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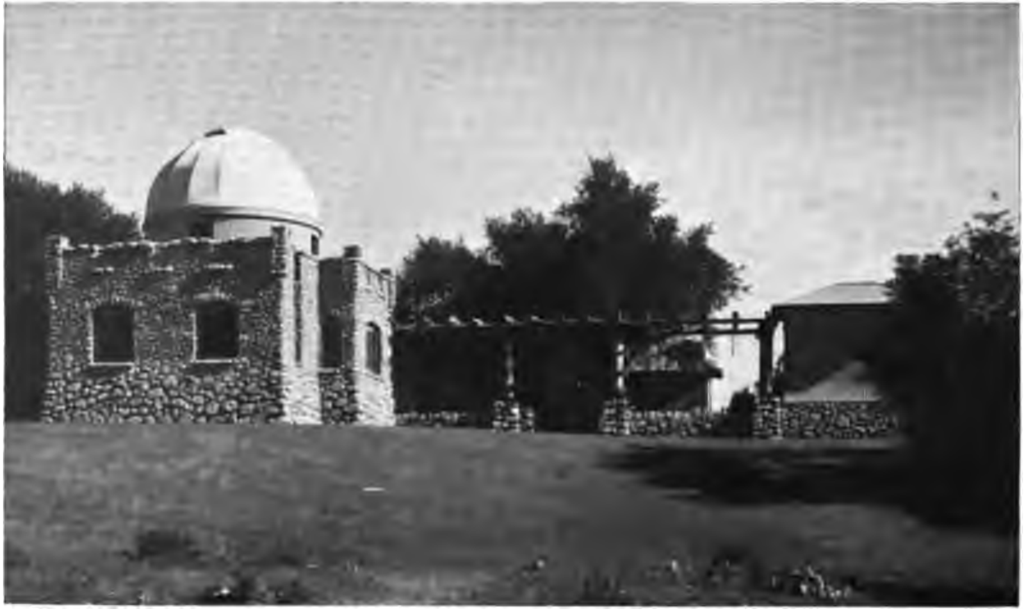

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Strassburg, Germany, Universitäts-Sternwarte.
Sydney, New South Wales, Observatory.
Tacubaya, Mexico, Observatorio Astronomico Nacional.
Tokio, Japan, University Observatory.
Toronto, Canada, Astronomical and Physical Society of Toronto.
Toulouse, France, Observatoire.
Turin, Italy, Osservatorio Astronomico.
University Park, Colorado, Chamberlin Observatory.
University of Virginia, Virginia, McCormick Observatory.
Upper Darby, Pennsylvania, Flower Observatory, University of Pennsylvania.
Upsala, Sweden, University Observatory.
Vienna, Austria, K. K. Sternwarte.
Vienna (Ottakring), Austria, Von Kuffnersche Sternwarte.
Washington, District of Columbia, Library of Congress, Periodical Division.
Washington, District of Columbia, National Academy of Sciences.
Washington, District of Columbia, Naval Observatory.
Washington, District of Columbia, Smithsonian Institution.
Washington, District of Columbia, The American Ephemeris.
Washington, District of Columbia, U. S. Coast and Geodetic Survey.
Williams Bay, Wisconsin, Yerkes Observatory.
Zurich, Switzerland, Observatory.

EXCHANGES.

Astrophysical Journal, Williams Bay, Wisconsin.
Popular Astronomy, Northfield, Minn.
Prof. Dr. H. J. Klein, Editor of *Sirius,* Theresien St. 85, Köln-Lindenthal, Germany.
The Observatory, Greenwich, England.
The Journal of the Royal Astronomical Society of Canada, Toronto, Canada.
Revista di Astronomia, Società Astronomica Italiana, Turin, Italy.
Society Astronomica, Italiana, Turin, Italy.
Royal Astronomical Society of Canada, Toronto, Canada.

FOR REVIEW.

[See *Publications* A. S. P., Vol. VIII, p. 101.]

The Call, San Francisco, California.
The Chronicle, San Francisco, California.
The Examiner, San Francisco, California.
The Mercury, San Jose, California.
The Record-Union, Sacramento, California.
The Times, Los Angeles, California.
The Tribune, Oakland, California.

MOUNTAIN SITES FOR OBSERVATORIES.

By A. G. McAdie.

The establishment of the Lick Observatory marked an epoch in astrophysical work in more ways than one. The selection of a high-level site on the Pacific Coast, where it was anticipated favorable atmospheric conditions would prevail, was a recognition of the importance of conducting future research under different conditions than those experienced by the great observatories of the world — situated at low levels and near centers of population. The establishment of observatories in South America, and within the past few years the inauguration of the Solar Physics Observatory at Mt. Wilson, Cal. (elevation about 6,000 feet), are but progressive developments along the line. In brief, it is now clearly recognized that work must be carried on where there is the greatest possible freedom from the atmospheric disturbances so common at low levels. Primarily the question of definition is all important, and there is little reason to doubt that in any observatory and almost in any line of work, the greatest possible improvement will be accomplished by securing the best possible definition. Unfortunately, instruments must be located upon the ground and not in the free air. It follows therefore that the astronomer is handicapped at the very outset by the instability of the lowermost air stratum—the air close to the ground. The tremulous character of air near the ground during both day and night hours materially affects the definition. If we stop to consider the loss and gain of heat in this level, we need not be surprised at the existence of marked convectional currents and stream lines, all tending to distort the wave-front and prevent perfect definition. Where day observing is necessary, as in solar work, we have a steadily increasing instability, due to the Sun's altitude, and all the unequal warming effects, due to radiation, convection, and conduction. One anticipates therefore that the best seeing is, as a rule, during the early morning hours; or when the atmosphere is nearly quiet and there is a minimum amount of dust or haze. At night the air near the Earth's surface is disturbed by cooling, due to radiation, and by warming, due to air motion and absorption of heat from other strata. The surface of the Earth is itself losing heat by radiation and receiving heat by slow conduction from the lower earth. Furthermore, the presence of water-vapor materially alters the heat distribution, since we have the latent heat of condensation set free during the cooling; and, conversely, a large amount of heat utilized in vaporizing water during the warming process. Nor is the radiation by gaseous matter the same as from the ground or water surfaces. In the former every particle radiates into space directly, whereas with the solid or liquid only a surface radiation occurs. Evidently then the problem is a complicated one; one in which we have to deal not only with the nocturnal cooling and diurnal warming of the Earth's surface, but also the cooling and warming of the atmosphere. Recent experiments indicate that there is at times well-marked stratification of the air and surfaces of discontinuity. This was shown to be possible by HERMANN VON HELMHOLTZ[1], in the formation of fog billows, where atmospheric strata of different density and temperature lie contiguous; and has been confirmed by recent determinations with kites and balloons. The *isothermal layer* which has just been discovered—a level at which there is a cessation of temperature distribution—is probably due to the absence of vertical convection, and is especially significant as indicating that the absorbing power of the atmosphere becomes a minimum chiefly because of the small quantity of water-vapor present at that height. To astronomers the existence of this isothermal layer is, as pointed out by Professor TURNER,[2] especially interesting in connection with atmospheric refraction. Assumptions heretofore made in connection with refraction no longer hold.

This isothermal level, however, is far beyond our reach. Its height is approximately 12,000 meters. What we are most concerned about at the present time is "good seeing," if attainable within a short distance above the ground. While what precedes shows that the full solution is not restricted to the layers of air next the ground, it has been found by LANGLEY,

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[1] Paper published in 1888, Royal Prussian Academy of Sciences; translated by ABBE, Smithsonian Institution, 1891.

[2] Section A, British Association Dublin Meeting. See *Nature*, October 1, 1908, p. 550.

HALE, ABBOT, and others, that within a height of one hundred feet above the ground material improvement can be had by, (1) having the telescope as high as possible above the ground,[1] and (2) by churning the column of air in the tube of the telescope (LANGLEY and ABBOT). The result of these innovations is to thoroughly mix the air and prevent the formation of layers of different density; also, preventing any undue heating of mirrors or of tubes. To some extent "boiling" can thus be eliminated. HALE proposes to further reduce the "heating effect by doing away with the tube and using shelter houses with canvas louvres, permitting free circulation of air, but shielding from direct insolation and radiation.

From all that precedes, then, it is evident that while perfect conditions need not be expected, considerable improvement is possible in the efficiency of observatories, both in the details of work and in the increased working hours, if future observatories are located at high levels, where cloudless, dry, dust-free, haze-free, and homogeneous atmospheric conditions prevail. It is not too much to say that, except for what may be called the general routine work of an observatory, present institutions at low levels have reached the limit of their efficiency. It would be unwise to equip such observatories with the powerful instruments of modern astrophysical research. HALE puts the case fairly when he says:—[2]

> "Even if the means were available for supplying the necessary instruments to existing observatories, they could not be successfully employed without atmospheric conditions much superior to those at present available."

There is one other aspect to be considered. Much astrophysical work to-day is concerned with the absorption and radiation of energy in the atmospheres of the Sun, the stars, and the planets. For example, ABBOT[3] shows that from

> ". . . the combined work of RUBENS, ASCHKINASS, LANGLEY, KEELER and VERY, NICHOLS (and his own) a tenth part of the average amount of water-vapor in the vertical column of atmosphere above sea-level is enough to absorb more than half of the radiation of the Earth through space, etc., and that the real surface which communicates the Earth's heat through

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[1] See HALE, "Study of Conditions for Solar Research at Mt. Wilson, Cal., 1905," p. 170.

[2] "Solar Researches at Mt. Wilson," pp. 159.

[3] *Annals of the Astrophysical Observatory*, p. 172.

space is the water-vapor and carbonic acid layer lying perhaps 4,000 meters above sea-level."

* * * * * *

No one recognized more clearly than Professor LANGLEY the importance of good seeing.[1] No one foresaw the necessity of high-level observatories in determining the true value of the solar constant in determinations of variability of solar radiation. As early as 1881 he proved the value of experimental work at a high level on the Pacific Coast, in a region less exposed to storm and with an atmosphere immeasurably superior, so far as the absence of dust and water-vapor are concerned, to any attainable elsewhere in our country. His classic researches on Mt. Whitney and Lone Pine should be repeated at the same points for many reasons. The value of the solar constant thus redetermined would approximate 2.1 calories per square centimeter per minute, and such a determination would be authoritative.

Mt. Whitney is to-day more accessible than when Professor LANGLEY made his experiments. It is believed that there are excellent localities close by at which temporary observatories could be erected. And what is true of this section of the High Sierra holds for other mountains on the Pacific Slope. In some ways the Sierra Madre are to be preferred, owing to the general condition of air steadiness; but it may be that for purposes which do not now appear sites in the northern ranges, extending perhaps to the Cascades, would be advantageous.

While the writer does not claim any special knowledge concerning availability of different sites in the mountains of the Pacific Slope, it so happens that he has made the ascent of and measured the three highest peaks on the Pacific Coast, excluding peaks in Alaska. These are Mt. Whitney, 14,502 feet; Mt. Shasta, 14,200 feet; and Mt. Rainier, 14,394 feet.

As the various data obtained on these ascents are not readily accessible, I give the following results of our observations, and some other general information:—

MT. WHITNEY, CALIFORNIA.

This peak is situated in latitude 36° 34′ 33″ N., and longitude 118° 17′ 32″ W.

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[1] *American Journal of Science*, 1903, p. 89.

References: LANGLEY, "Researches on Solar Heat"; Professional Paper No. 15; Signal Service, 1884; WHEELER, "Surveys West of the 100th Meridian, 1889"; STEWART, *Mount Whitney Club Journal,* Visalia, Cal.; LE CONTE, *Sierra Club Bulletin;* MCADIE, *Sierra Club Bulletin,* June, 1904; and *Monthly Weather Review,* 1903.

The mountain can be reached in several ways; from Lone Pine on the Carson and Colorado Railroad; by trail from Kern River to Langley's Camp, 3,000 feet below the summit; and from the northern end of the Kern River. A good climber can go from Langley's Camp to the summit in less than four hours.

On September 2 to 6, 1881, Professor LANGLEY made eighteen simultaneous observations at Lone Pine and Mt. Whitney. The means of the eighteen observations for pressure and temperature are as follows:—

Lone Pine.

Pressure	26.018 inches	660^{mm}.9
Temperature	69°.6	20°.9 C.

Mt. Whitney.

Pressure	17.586 inches	446^{mm}.6
Temperature	37°.2	2°.9 C.

MCADIE and LE CONTE obtained a mean pressure from eight readings, corrected for tempearture, scale, capillarity, and gravity, of 17.694 inches (449^{mm}.4) at the summit of Mt. Whitney, and mean temperature of 52° F. (11°.1 C.).

Various wet-bulb readings have been obtained by LANGLEY, WHEELER, CAMPBELL, and ABBOT, all showing extreme dryness, and relative humidity varying from ten to twenty per cent.

HALLECK, with a temperature of 34° F. (1°.1 C.), determined boiling-point to be 186°.4 F. (86° C.). HUTCHINGS reports the boiling-point at 187° F.

MT. RAINIER, WASHINGTON.

This peak is a volcanic cone, situated in latitude 46° 51′ 5″ N., and longitude 121° 45′ 28″ W.

References: BAILEY WILLIS, U. S. Geological Survey papers; *Mazama Club Bulletin,* Portland, 1905-6; *Sierra Club Bulletin,* 1905.

The mountain can be climbed from different sides, but probably the safest and easiest way is from Ashford, via Longmyers, to Paradise Valley.

On July 25, 1905, the following observations were made by A. G. McAdie and checked by Professor J. N. Le Conte:—

Mercurial barometers, Green Standard No. 1664 and No. 1554. Four readings, at Columbia Crest, summit of Mt. Rainier; mean pressure corrected for temperature, instrumental error, and gravity, 17.663 inches, 448^{mm}.6. Mean temperature at summit, 39° F. (3°.9 C.); mean temperature of air column from readings at summit and sea-level, 50° F. (10° C.). The sea-level pressure reading, mean of Tacoma, Seattle, Portland, and Spokane, was 29.960 inches. The height, as determined by us, 14,394 feet (4,387 meters).

The boiling-point, as determined on the south rim of the crater, probably thirty meters below the true summit, was 187°.4 F. (86°.4 C.).

A sling psychrometer gave the following temperatures:—

Dry bulb,	37° F.,	36°.4,	36°.5,	36°.5,	37°.0,	mean 36°.7 F.
Wet bulb,	32	28 .0,	25 .0,	24 .2,	25 .5,	mean 26 .9

The dew-point was approximately 10°; the vapor pressure, 0.07 of an inch; relative humidity, thirteen per cent.

MT. SHASTA, CALIFORNIA.

This peak is situated in latitude 41° 24′ 28″ N., and longitude 122° 11′ 49″ W.

The following observations were made on the summit of Mt. Shasta on August 5, 1905:—

Six pressure readings. Mean pressure, corrected for temperature, instrumental error, and gravity, 17.993 inches; mean temperature of air column, 60° F.

The height, as determined by us, 14,200 feet (4,329 meters). The boiling-point at the summit, as then determined, 187°.7 F. (86°.5 C.).

In our work we fully recognize that the mean temperature of the column of air is a very uncertain quantity. The air is seldom in rest. On the dates of our ascents we noted marked stratification. Above the 10,000-foot level (3,048 meters) the drift of the air appeared to be entirely different from the motion of the lower levels.

ASTRONOMICAL OBSERVATIONS IN 1908.

MADE BY TORVALD KÖHL, AT ODDER, DENMARK.

VARIABLE STARS.

(The instrument used is a 3-inch Steinheil, power 42.)

S *Ursæ Majoris*.[1]

Jan. 2: $S\begin{cases} > e. \\ < d. \end{cases}$
4: id.
5: < d.
10: 1 step < d.
13: = d.
14: id.
18: id.
20: id.
21: id.
28: id.
29: id.
31: id.
Feb. 2: 1 step > d.
6: 2 steps > d.
8: id.
10: id.
16: id.
19: { in the midst between d and c.
23: 2½ steps > d.
29: { in the midst between d and e.
Mar. 23: 1 step > e.
24: = e.
25: 1 step < e.
26: id.
27: id.
28: 2 steps < e.
29: id.
30: 3 steps < e.
Apr. 1: 4 steps < e.
2: 3 steps > f.
3: id.
6: id.
7: id.
Apr. 8: id.
19: 1 step > f.
May 1: = f.
11: = g.
18: $\begin{cases} < g. \\ > h. \end{cases}$
20: id.
Aug. 14: 1 step > d.
17: 2 steps > d.
23: id.
24: id.
27: id.
29: 1 step > d.
31: 2½ steps > d.
Sept. 3: 3 steps > d.
9: id.
16: 5 steps > d.
19: 6 steps < c.
22: 5 steps < c.
24: id.
25: id.
30: 5 steps > d.
Oct. 3: id.
5: id.
10: 4 steps > d.
18: 1 step < d.
22: 2 steps > d.
Nov. 1: = e.
6: id.
8: id.
16: { in the midst between e and f′.
26: 2 steps > f.
29: $\begin{cases} < f. \\ > g. \end{cases}$

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[1] Vide the sketch in the *Publications A. S. P.*, No. 73, **12**, 56.

T *Ursæ Majoris.*[1]

Jan. 2: T 5 steps > a.
4: 4 steps > a.
5: id.
10: 2 steps > a.
13: 1 step > a.
14: id.
18: 2 steps > a.
20: 1½ step > a.
21: 2 steps > a.
28: 1 step < a.
29: id.
31: id.
Feb. 2: 2 steps < a.
6: < b. > c.
8: 1 step < b.
9: id.
10: 2 steps > c.
16: id.
19: in the midst between c and d.
23: 1½ step > d.
29: in the midst between d and e.
Mar. 18: < e.
23: = f.
24: < f. > g.
25: id.
26: 1 step > g.
27: = g.
28: id.
29: 1 step < g.
30: id.
Apr. 1: very faint.
2: id.
3: id.
6: id.
7: id.
Apr. 8: invisible.
15: id.
16: id.
19: id.
20: id.
May 11: id.
18: id.
20: id.
Aug. 14: < b. > c.
17: 1 step > b.
23: < a. 2 steps > b.
24: < a. > b.
27: 1 step > a.
29: 2 steps > a.
31: 1 step > a.
Sept. 3: 2 steps > a.
9: 3 steps > a.
16: id.
19: 4 steps > a.
22: id.
24: id.
25: id.
30: = a.
Oct. 3: id.
5: = b.
10: id.
18: = c. (?)
22: < c. > d.
Nov. 1: 1 step < d.
4: 3 steps > e.
6: id.
8: id.
16: id.
26: = g.
29: = f = g.

The comparison stars f and g are found to be a little variable. August 24th, I have noted: g 1 step > f. On November 29th: f = g. Usually I note: f > g, the difference being only 1 step. B. D. has f = g = $9^m.5$; Harvard has f = $10^m.75$, g = $10^m.40$.

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[1] Vide the sketch in the *Publications A. S. P.*, No. 22, 4, 63.

W *Pegasi.*[1]

Jan. 1: W = b.
2: in the midst between b and c.
4: < b.
> c.
5: id.
14: 1 step > c.
18: = c.
20: id.
21: 1 step < c.
29: 3 steps < c.
31: 1 step > d.
Feb. 2: 1½ step > d.
9: 1 step > d.
19: = e.
29: in the midst between e and f.
Aug. 14: < g.
> h.
18: = h.
23: id.
Aug. 24: id.
27: < g.
> h.
29: id.
31: id.
Sept. 3: id.
4: id.
12: id.
16: a little > h.
20: < g.
> h.
24: = g.
25: = f.
30: id.
Oct. 3: 1 step< f.
5: id.
18: 1 step < e.
Nov. 8: 2 steps < c.
16: 1 step < b.
26: = b.
29: id.

SS *Cygni.*[2]

Jan. 1, 6^h: SS = g.
2, 9^h: < g.
4, 6^h: = h.
5, 7^h: very faint.
14, 6^h: invisible.
18, 6^h: id.
20, 6^h: id.
21, 7^h: id.
29, 7^h: 1 step < b.
31, 7^h: = b.
Feb. 2, 7^h: < b.
2 steps > c.
6, 6^h: 2 steps > d.
9, 6^h: = e.
16, 7^h: invisible.
19, 7^h: very faint.
Apr. 20, 12^h: invisible.
21, 10^h: id.
26, 11^h: id.
May 1, 11^h: 1 step < e.
9, 10^h: 1 step < c.
May 11, 11^h: 3 steps >c.
1 step< b.
15, 10^h: 1 step > c.
18, 11^h: 1 step < c.
20, 12^h: = d.
Aug. 14, 10^h: > e.
< d.
15, 10^h: in the midst bet. d and e.
17, 11^h: < e.
18, 10^h: 4 steps < e.
23, 10^h: = f.
24, 10^h: > f.
< e.
27, 10^h: 1 step > f.
29, 10^h: > f.
< e.
31, 10^h: = e.
Sept. 3, 10^h: = e.
4, 9^h: > f.
< e.

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[1] Vide the sketch in the *Publications A. S. P.*, No. 60, **10**, 23.
[2] Vide the sketch in the *Publications A. S. P.*, No. 100, **17**, 18.

Sept. 9, 9^h: = d.
11, 8^h: 2 steps < c.
12, 8^h: 1½ step < c.
16, 9^h: 2 steps > c.
19, 9^h: $\left\{\begin{array}{l}\text{in the midst}\\ \text{bet. b and c.}\end{array}\right.$
20, 8^h: b(3)SS(2)c
23, 8^h: $\left\{\begin{array}{l}< \text{c.}\\ > \text{d.}\end{array}\right.$
24, 10^h: = d.
25, 9^h: 2 steps < d.
30, 12^h: 4 steps < d.
Oct. 1, 10^h: id.
3, 9^h: = e.
Oct. 5, 8^h: $\left\{\begin{array}{l}< \text{d}'.\\ > \text{e.}\end{array}\right.$
18, 9^h: d′(3)SS(2)e
Nov. 1, 8^h: $\left\{\begin{array}{l}< \text{d}'.\\ > \text{e.}\end{array}\right.$
4, 8^h: = e.
6, 9^h: = e(?).
8, 7^h: d′(3)SS(2)e
14, 7^h: 2 steps > c.
16, 8^h: = d.
26, 6^h: = e.
29, 6^h: 1 step > f.

Z *Cygni*.[1]

Jan. 1: Z 2 steps > a.
2: 1 step > a.
4: < a.
5: $\left\{\begin{array}{l}< \text{a.}\\ > \text{b.}\end{array}\right.$
14: 1 step > a.
18: 2 steps > a.
20: 1 step > a.
21: id.
28: = a.
29: 2 steps > a.
31: 1 step > a.
Feb. 2: = a.
6: = b.
16: 2 steps > b(?).
19: = b.
Mar. 25: very faint.
Apr. 1: id.
20: invisible.
21: id.
26: very faint.
May 1: faint, < e.
9: invisible.
15: id.
18: id.
20: id.
Aug. 14: id.
18: id.
23: id.
Sept. 3: = e.
9: $\left\{\begin{array}{l}> \text{e.}\\ < \text{d.}\end{array}\right.$
11: $\left\{\begin{array}{l}> \text{d.}\\ < \text{c.}\end{array}\right.$
16: id.
19: = d.
22: $\left\{\begin{array}{l}> \text{c.}\\ < \text{b.}\end{array}\right.$
24: id.
30: = b.
Oct. 3: = b′.
5: id.
18: $\left\{\begin{array}{l}< \text{a.}\\ > \text{b}'.\end{array}\right.$
Nov. 1: = b′.
4: = b.
6: 1 step > b.
8: 1½ step < b.
14: 1 step < b.
16: $\left\{\begin{array}{l}< \text{b.}\\ > \text{c.}\end{array}\right.$
29: = d.

Y *Tauri* (B. D. + 20° 1083).

A number of forty comparisons have been made upon this irregular variable star, which during the whole year was either equal to or some steps brighter than the star A = B. D. + 20° 1095 ($7^m.4$). In February, March, and April the star Y had reached its maximum ($7^m.1$), but in January and November it had decreased a few steps.

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[1] Vide the sketch in the *Publications A. S. P.*, No. 100, **17**, 16.

U *Herculis.*

Apr. 20:	U invisible (?).
26:	2 steps < h.
May 1:	id.
18:	1 step > h.
20:	id.
Aug. 15:	= a.
17:	$\left\{\begin{matrix} > c \\ < a \end{matrix}\right\}$ b > a.
18:	2 steps < a.
23:	id.
24:	id.
27:	id.
29:	id.
31:	= c.
Sept. 3:	id.
4:	1 step > c.
9:	½ step > c.
Sept. 11:	< c. > d.
12:	= c.
16:	< c. > d.
19:	C(2)U(3)d.
22:	id.
23:	in the midst between c and d.
24:	id.
25:	C(3)U(2)d.
30:	id.
Oct. 3:	= d.
5:	2 steps > d.
10:	1 step > d.
18:	= e.
Nov. 29:	2 steps < f.

I have used the sketch in the *Publications A. S. P.*, No. 106, **18**, 52, drawn by Miss ROSE O'HALLORAN, but have added the two small neighboring stars g at a and h at f, both northward.

A SUSPECTED VARIABLE STAR.

138.1908 *Herculis.*

During my observations upon U *Herculis* my attention was directed to the two comparison-stars,

a = B. D. + 19° 3096 $7^m.0$.
b = B. D. + 19° 3089 $7^m.8$.

The star b is here eight steps fainter than a. On August 5, 1907, I found b > a, and so I have seen it until October, 1908. On October 5th, 10th, and 18th, I have noted: b 2-3 steps < a. But when the ocular was screwed out the reddish star a was "diminished," and then seemed to be equal to or even dimmer than b. In A. G. Berlin A 5856 is

$a = 7^m.2$
$b = 7^m.7$,

and in *Harvard Annals,* **37,** 170 and 183, we find

$$a = 7^{m}.36$$
$$b = 7^{m}.39.$$

Whether the variable is a or b is still difficult to decide. According to its red color, it might perhaps be the star a, though a look at the differences might point out b as the variable one. It will be necessary to compare b with a and c. (Vide *Astronomische Nachrichten,* No. 4274, **179,** 29.)

METEORS.

Fireballs have been observed from stations in Denmark at the following dates: January 3d, 21st; March 2d, 16th, 25th; April 8th, 15th; May 1st, 11th, 29th; June 25th, 26th; July 2d, 20th, 21st; August 6th, 20th; October 7th, 24th; November 8th, 21st; December 3d, 7th.

SHOOTING-STARS.

A little swarm of shooting-stars, during five minutes more than thirty meteors, was observed on January 2d, $8^{h}\ 10^{m}$–$8^{h}\ 20^{m}$, at Hjörring, Denmark, radiant = 300° + 61°; and on January 3d, $11^{h}\ 23^{m}$–$12^{h}\ 42^{m}$, seventeen large shooting-stars were mapped at Paderborn, Germany. (Vide *Astronomische Rundschau,* No. 98, and *Astronomische Nachrichten,* No. 4263, **178,** 255.) On June 25th, $10^{h}\ 30^{m}$, an observer at Odense, Denmark, mapped a most interesting twin-meteor, two shooting-stars with parallel paths, with a distance of ½°, one on each side of the pretty star *Arcturus.*

The weather was, in the year 1908, quite unfavorable for the planned observations on shooting-stars in August, and after November 29th the sky was overcast with clouds every night here at Odder.

The above-mentioned estimations of variable stars have often been controlled by my young assistant, JÖRGEN FOG.

PLANETARY PHENOMENA FOR MARCH AND APRIL, 1909.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

Full Moon....	Mar. 6,	$6^h 56^m$ P.M.	Full Moon....	April 5,	$12^h 28^m$ P.M.
Last Quarter..	" 14,	7 42 P.M.	Last Quarter..	" 13,	6 30 A.M.
New Moon....	" 21,	12 11 P.M.	New Moon....	" 19,	8 51 P.M.
First Quarter..	" 28,	8 49 A.M.	First Quarter..	" 27,	12 36 A.M.

The vernal equinox, the time when the Sun crosses the equator from south to north, occurs March 20th, 10 P.M., Pacific time.

Mercury is a morning star on March 1st, and continues to be such until April 21st. It then passes superior conjunction with the Sun and becomes an evening star. Greatest west elongation is passed on March 9th. The planet's apparent distance from the Sun is 27° 26′. This is greater by 9° than the greatest east elongation in January, and is due to the circumstance that the time of perihelion passage was about the same as the January east elongation, while the March west elongation occurs within a week of aphelion time. Conditions for visibility of *Mercury* as a morning star during the spring months are seldom good, but for this year the planet will rise more than an hour before sunrise during the first two weeks of March, and it can be seen as a morning star nearly as well as it could be seen as an evening star in January. After passing superior conjunction, on April 21st, it moves rapidly away from the Sun, and by the end of the month it sets nearly an hour after sunset. *Mercury* is in close conjunction with *Saturn* on April 13th and with *Venus* on April 19th, but the planets are then too near the Sun for naked-eye view.

Venus is a morning star on March 1st, and remains such until April 28th. It then passes superior conjunction with the Sun and becomes an evening star. On March 1st it is only about 14° away from the Sun and is at the same time about 7° south of that body; so it rises only a trifle more than half an hour before sunrise, and it will scarcely be possible to see it, although the greater brightness of *Venus,* even when at its greatest distance from us, as it is at superior conjunction, makes it a much easier object than *Mercury,* when they are at the same apparent distance from the Sun. After the opening days of March it will certainly be too near the Sun for naked-eye visibility until some time after it becomes an evening star.

Mars rises a little after 3^h A.M. on March 1st, and at about $1^h\ 40^m$ A.M. on April 30th. It moves, during the two months, about 43° eastward and 5° northward from a position in *Sagittarius* north of the handle of "the milk-dipper" group to the eastern part of *Capricorn.* No very bright stars are near its path. Its distance from the Earth is still rapidly diminishing from 151,000,000 miles on March 1st to 104,000,000 miles on April 30th, and there is a consequent increase in brightness of a little more than one hundred per cent during the two months' period. At the end of April, however, it is still nearly three times as far away from us as it will be at the time of opposition in September, and only about one ninth as bright. On the afternoon of March 26th it is in conjunction with *Uranus,* passing only 18′, a little more than one half of the Moon's apparent diameter, to the south. For a day or two before and after conjunction the planets will be near together.

Jupiter was in opposition to the Sun on the last day of February. It is therefore above the horizon practically the entire night during early March. By the end of April it rises early in the afternoon and sets at about $2^h\ 30^m$ A.M. It continues to retrograde,—that is, move westward,—not quite 5° during the two months, and 2° northward, toward *Regulus,* *α Leonis,* and at the end of April is only about 6° east of that star. Toward the close of April the westward motion becomes very slow, and it ceases on May 1st. After that date the planet resumes its general eastward motion.

Saturn is an evening star on March 1st, setting a little more than two hours after sunset. The Sun in its eastward motion among the stars rapidly overtakes the planet and passes it on the morning of April 3d. The planet then becomes a morning star and lags behind the Sun, so that by the end of the month it rises nearly an hour before sunrise. During a considerable part of the two months' period *Saturn* is too near the Sun for naked-eye observation.

Uranus rises shortly after 4^h A.M. on March 1st, and shortly after midnight on April 30th. It is in the constellation *Sagittarius* and moves a fraction of a degree eastward until April 25th, when it becomes stationary. Its conjunction with *Mars* on March 26th has been noted.

Neptune is nearly stationary in *Gemini.*

EIGHTH AWARD OF THE BRUCE MEDAL.

At a meeting of the Board of Directors of the Astronomical Society of the Pacific, held on November 28, 1908, the Bruce Gold Medal of the Society was awarded to Doctor George W. Hill, of West Nyack, New York, for distinguished services to astronomy. The presidential address, reviewing the life and works of the eighth recipient of this medal, will be delivered at the annual meeting of the Society, to be held in San Francisco on March 27th.

NOTES FROM PACIFIC COAST OBSERVATORIES.

THE FRANK P. BRACKETT OBSERVATORY OF POMONA COLLEGE, CLAREMONT, CALIFORNIA.

Pomona College has recently dedicated a new observatory. The building was presented by Mr. LLEWELLYN BIXBY, an alumnus of the college, and named for a former teacher, now the director of the observatory. It is a small building, designed primarily for student work. It contains a six-inch equatorial with Clark objective and Gaertner mounting; a three-inch transit and a chronograph, also made by Mr. GAERTNER; and a Riefler mean-time clock. A smaller laboratory clock will be used for sidereal time until another Riefler clock can be purchased.

A horizontal solar telescope, with six-inch objective and a focal length of forty feet, is nearly completed. This is to be used with a spectrograph of the Littrow type, having a focal length of fifteen feet. The cœlostat has two mirrors—one, a flat mirror ten inches in diameter, is driven by clock-work so as to reflect the light from the Sun upon the second; also a flat mirror twelve inches in diameter, which is mounted with alt-azimuth motion on a column just south of the first. From this mirror the light passes through the objective which is mounted on a pier north of the cœlostat. The cœlostat was built by Mr. GAERTNER, its mirrors and the objectives of both telescope and spectrograph being made by M. PETITDIDIER, of Chicago.

The cœlostat and objective of the horizontal telescope rest upon a concrete foundation and are covered by a small house which runs upon a track, so that it can be entirely removed when the instrument is in use. This house is connected with the main building by a pergola, which will be covered with vines to shelter the beam of light in its passage from the objective to the slit. The slit of the spectrograph and the plate-holders are placed in the focal plane of the forty-foot objective, upon a concrete pier in the observatory, near the south side. The grating and the lens, which serves as both collimator and camera lens, are mounted upon another pier fifteen feet north of the first.

The building is made of stone and stands on a slight elevation in the park, well removed from other buildings and from ordinary travel. A flat roof or deck floor covers the building, except the central portion where the dome-room stands. This deck, protected by the parapet which crowns the walls, affords a good place for direct observation of the sky.

The opening of the observatory was the occasion of a notable address by Dr. George E. Hale, Director of the Mt. Wilson Solar Observatory, announcing some important discoveries recently made at Mt. Wilson concerning the vortical character of sun-spots.

VISIBILITY OF MT. WHITNEY FROM MT. HAMILTON.

It has been the tradition at Lick Observatory that Mt. Whitney could not be seen from Mt. Hamilton because of an intervening mountain.

A year or two ago, when the air was unusually clear after some of the winter storms, the Sierras could be traced almost to their extreme southern end. A coffin-shaped peak was noticed then which looked very much as the pictures of Mt. Whitney would lead one to expect. So striking was the resemblance that the bearing of Mt. Whitney from Mt. Hamilton was determined from their known geographical positions.

Just recently the Sierras were exceptionally clear and the same peak was visible, as well as the outlines of a nearer dark range projected against the snow of the more distant range. The bearing of the peak supposed to be Whitney was measured with a surveyor's transit. Following are the computed and observed directions:—

Computed bearing of Mt. Whitney from Lick Observatory, main building—16 ° 28′ south of east.

Observed bearing of Mt. Whitney from Lick Observatory, main building—16° 30′ south of east.

Distance, 191 miles.

An examination of the topographical maps of that region, published by the U. S. Geological Survey, shows that about ten miles this side of Mt. Whitney there is a group of peaks known as Milestone Mountain, the highest of which is given as 13,682 feet. I find, however, that the line of sight to Mt. Whitney passes just south of the Milestone peaks.

As further tending to identify Mt. Whitney, there is a sharp, isolated peak just to the north, in the proper direction for a peak on the map named Mt. Russell, whose altitude is 14,190 feet.

The close agreement of the directions, together with the appearance and facts above noted, convince me that it is Mt. Whitney which we see. C. D. PERRINE.

MT. HAMILTON, CAL., January 18, 1909.

NOTE ON THE SPECTRUM OF COMET *c* 1908 (MOREHOUSE).

In *Lick Observatory Bulletins* Nos. 145 and 147 the writers have published the results of the spectroscopic observations, both visual and photographic, of Comet *c* 1908. In the early visual observations Mr. CAMPBELL noticed that the spectrum had unusual features. The carbon bands at λ 4737, λ 5165, and λ 5635 were present in their usual relative intensities, but three bands to the violet of λ 4737, and a feeble one near $H\beta$ seemed to be new, or at least in very much greater relative strength than in previous comets observed at Mt. Hamilton. Four spectrograms of the comet were secured. The new lines (or bands) were recorded strongly, with the exception of the one near $H\beta$, for which region the plates used are not very sensitive.

The continuous spectrum seems to be almost entirely absent —all but a few per cent. of the photographic light being concentrated in seven lines at λ 3913, λ 4003, λ 4023, λ 4255, λ 4276, λ 4549, and λ 4571, in two lines at λ 4690 and λ 4715 which are probably the edges of flutings in the fourth carbon band, and in two lines at λ 3869 and λ 3883 which are due to cyanogen. We are unable to suggest a probable origin for the first seven lines mentioned. The six lines between λ 4003 and λ 4571, both inclusive, are no doubt identical with three pairs of lines observed by CHRÉTIEN[1] in the spectrum of

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[1] *Comptes Rendus*, **145**, 549. 1907.

Comet *d* 1907, and three bands observed by DESLANDRES[1] and EVERSHED,[2] all using objective-prism spectrographs. Radiations having these wave-lengths seem to be relatively strong in the tails of comets, as it is difficult otherwise to account for their essential absence from the spectra of the heads of Comet *d* 1907 and other comets, as observed with slit-spectrographs.

The most striking feature of the spectrograms is the nearly complete concentration of the light in pairs of lines (or bands) with intervals between the pairs approximately proportional to the wave-lengths of the lines;—that is, $\frac{\Delta\lambda}{\lambda}$ is constant, within the unavoidable errors of observation. The existence of these pairs of lines, with the lines in the pairs separated by about the same intervals, is strongly suggestive of closely related origins. The most promising hypothesis as to their origin seems to us to be that they are related to each other in much the same way as the well-known carbon bands or cyanogen bands are related. We are inclined toward the opinion that the six lines referred to may be the edges of flutings in three bands of some element or compound not yet observed in the laboratory.

In an important paper on the comet spectrum, M. DESLANDRES[3] expresses the opinion that the doubling of the lines is "probably a Doppler effect." As the relation, $\frac{\Delta\lambda}{\lambda} =$ constant, always holds for displacements of the lines throughout a spectrum by virtue of the motion of the light source in the line of sight,—the Doppler-Fizeau effect,—we had considered this explanation, but discarded it as improbable. It may be of value to state briefly the reasons which led us to look for a different explanation.

The pairs of bright lines or bands forming the basis of this discussion are: λ 4003-23, λ 4255-76, and λ 4549-71. Possibly the lines at λ 4690 and λ 4715 may also be included, but we feel confident that they are parts of the blue carbon band usually observed in comet spectra. The interval between the pairs, as observed by DESLANDRES on October 14th and November 1st, and by us on November 28th, remained constant within the errors of observation, and amounted to about twenty-one tenth-meters in the $H\gamma$ region. As a Doppler-Fizeau effect, this corresponds to a relative motion of 1450^{km} per second in the line of sight.

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[1] *Comptes Rendus,* **145**, 445. 1907.

[2] *Monthly Notices R. A. S.,* **68**, 16, 1907.

[3] *Comptes Rendus,* **147**, 951, 1908.

Assuming the inner section of the tail to lie, as usual, in the prolongation of the radius vector, the observed speed of 1450^{km} would be the projected equivalent of speeds of 2040, 2240, and 1840^{km} per second along the tail, or of 2040, 1920, and 2380^{km} per second transverse to the tail, respectively, on the three dates quoted.

The spectrograms show that by far the greater part of the photographic light of the comet's head and inner tail,—and perhaps of the entire tail,—falls in the six lines in question; which major part is divided about equally between the more refrangible and the less refrangible components.

The integrated image recorded by the ordinary camera should give results as to velocity not out of harmony with those indicated by the six lines into which the tail is chiefly resolved by the prism. These integrated images show by means of condensations within the tail that the speeds along the tail are of moderate and ordinary dimensions, not exceeding 30 or 40^{km} per second within say a million kilometers of the nucleus. Judging by the great brilliancy of many of the condensations, by the sharp bends, in which all the radiating material seems to fall, and by the fact that nearly all the brilliant part of the tail possesses a common general curvature, it does not seem that there can be much light radiated by matter moving fifty or sixty times as rapidly. Small and very narrow streamers are sometimes developed to considerable lengths between two successive dates, indicating probable speeds up to 200^{km} per second, but these emit only a small percentage of the total light of the tail, and therefore cannot have exerted an appreciable influence upon the observed spectrum.

The theory of a relative motion transverse to the axis of the tail, equal to $1900\text{-}2400^{km}$ per second, seems to meet with difficulties equally great. We should not expect rays of any known kind representing one component, or both components, of the three pairs of lines,—i. e., three eighths and perhaps three quarters of all the photographic radiations,—to move transversely to the tail, either along straight lines into distant space, or by rotation, without the ordinary integrated images showing the effects. The photographs of the present comet suggest rotational effects,[1] but on too small a scale.

If a transverse motion were radial with reference to the nucleus and to the axis of the tail it would seem that a slit of the width employed should have a broad band for its image instead of two widely separated lines or bands, at least in the vicinity of the nucleus. If the motion were rotational, either a wide or a narrow slit should give a single line or band,—unless the tail were hollow and the slit took in both of its brightened borders. The integrated images show no such bright-bordered tails.

We judge that the prismatic-objective spectrograms obtained by PLUVINEL and by DESLANDRES show the two component images of a pair to be similar and parallel, at least out to a considerable distance in the tail. It seems improbable that any conditions, electrical or otherwise, would favor uniform speeds,—either radial or rotational,—throughout a long section of the tail.

Perhaps the strongest evidence against the Doppler-Fizeau explanation of the pairs lies in the apparent constancy of the intervals. These were observed to be the same on the three days, October 14th, November 1st, and November 28th; whereas, from the changed angle at the comet between its radius vector and our line of sight, we should have expected the intervals in the pairs to vary four or five tenth-meters from November 1st to November 28th, whether the assumed cause of the doubling be motion along or transverse to the tail. Such a variation did not occur. It should be noted that CHRÉTIEN'S observations of Comet *b* 1907, August 16th-18th, gave an average interval of twenty-two tenth-meters for the three pairs of lines, with the angle at the comet equal to 77°. The corresponding speeds would be 1550^{km} per second along the tail and 6900^{km} transverse to the tail. The intervals obtained by CHRÉTIEN for the three pairs of lines were respectively eight, seventeen, and thirty-nine tenth-meters. Whether the wide range in the values is real or accidental, due to the faintness of the lines in that comet, we cannot judge.

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[1] Especially noteworthy in this connection are the observations by BALDET and QUENISSET, in *Comptes Rendus*, **147**, 1033, 1908.

The possible existence of an $H\beta$ radiation, as reported by Mr. CAMPBELL for October 20th, may prove of interest in connection with the suggested canal-ray Doppler-Fizeau effect.

As stated in our former paper on the spectrum, we incline to the view that the lines are observed nearly in their normal positions, and that the double lines are possibly the edges of flutings in bands not yet observed and identified in the laboratory. In this connection we should not overlook the faint lines at λ 453- and λ 423-, which may be the edges of other and fainter flutings in the same bands. Attention should be called to the strong line at λ 3913, which is not doubled. It seems to stand alone in this regard.

If we take either the more refrangible or the less refrangible component of each of the four pairs of lines between λ 4002 and λ 4715 and form the successive differences in the wave-lengths, we find that the second differences are constant within the errors of observation. This may indicate, as the source of these radiations, a substance or compound closely related to carbon.

Inasmuch as an identity has been shown to exist between certain comets and meteor streams, and laboratory analyses have shown meteorites to differ widely in chemical composition, it would not seem surprising that there should be different types of comet spectra.

It is hoped that PLUVINEL and DESLANDRES have been able to obtain observations additional to those already published which shall test thoroughly the various explanations suggested. Dr. CURTIS, in charge of the D. O. Mills Observatory at Santiago, Chile, has been asked to secure an extensive series of spectrograms with a one-prism slit spectrograph and with an improvised objective-prism spectrograph during the several months that the comet will be favorably situated for observers in the southern hemisphere.

W. W. CAMPBELL,
SEBASTIAN ALBRECHT.

January, 1909.

THE BRIGHTNESS OF THE CORONA OF JANUARY 3, 1908.

The attempt by the writer to determine the total brightness (photographic) of the corona of August 30, 1905, was not successful, owing to the thin clouds. Two negatives, together with some exposures on the preceding full Moon, were secured. These have little value, however, except to confirm the conclusion, reached from the 1908 eclipse, that most of the light of the corona emanates from within one minute of the Sun.

The attempt was repeated at the eclipse of January 3, 1908, when entirely successful observations were obtained. The details of these observations and a discussion of them will be published as a *Lick Observatory Bulletin.* Only the results will be given here.

The effect of the coronal light was obtained by allowing it to shine through an aperture on a sensitive plate, without the intervention of any optical parts whatever. On these same plates were impressed standard intensity squares for comparison.

From these negatives were obtained:—

1. The total actinic brightness of the corona.
2. The actinic brightness of the sky surrounding the Sun.
3. The limits from within which practically all of the effective light of the corona emanates.

It was found that nearly all of the effective light of the corona came from a ring around the Sun not over 1′ wide. Outside that limited region the light of the corona, although visible to the eye conspicuously, was not strong enough in comparison to be distinguishable.

The light from the above narrow region was found to equal 6.0 lamp units. The light from the full Moon, at its mean distance, was found to be 55.6 lamp units. The region of the corona observed gave, therefore, 0.108 as much light as the full Moon. This amount should be increased by the fainter parts of the corona, the brightness of which has not yet been determined.

The average intrinsic brightness of the narrow region of the corona observed was found to be 2.07 lamp units; that of the Moon, 2.65 lamp units. As the brightest parts of the narrow coronal ring are easily two, or possibly three, times the *average* brightness, the brightest parts of the corona are, therefore, brighter intrinsically than the full Moon.

This result accords with the naked-eye view of the corona, which shows a very brilliant and very narrow ring of light immediately surrounding the dark body of the Moon.

The light of the sky around the bright corona, from an area of 40,900 square minutes, was found to equal 3.0 lamp units. This gives an *average* intrinsic actinic brilliancy of .0026 as compared with the lamp, or of .001 as compared with the surface of the full Moon.

The intrinsic brilliancy of the region of corona observed is found to be eight hundred times that of the surrounding sky.

C. D. PERRINE.

MT. HAMILTON, CAL., January 27, 1909.

RESULTS OF FURTHER STUDIES ON THE STRUCTURE OF PHOTOGRAPHIC FILMS.

In a previous paper I gave the conclusion that the principal cause of the large discordances in measures of star photographs was to be found in the size and irregular arrangement of the silver grains composing the star image. Further investigations were undertaken to eliminate some of the trouble from these sources.

The details of the recent investigations will appear in a *Lick Observatory Bulletin,* and only the general results will be given here.

It was found that the accuracy was materially increased by giving sufficient exposure to insure light action entirely through the film, and full but slow development to give greater uniformity to the grain.

Rapid plates with an increased proportion of silver yield more accordant measures than plates with the normal amount of silver.

Where the structure is sufficiently uniform, as in Seed 23, and Transparency plates, it was found possible, by observing the above requirements, to produce negatives such that the range among the measures is only twice the uncertainty of the measures themselves.

Thin films appear to give much more reliable results than thick ones.

C. D. PERRINE.

MT. HAMILTON, CAL., January 22, 1909.

NOTE CONCERNING VOLUME VIII, "PUBLICATIONS OF THE LICK OBSERVATORY."

The volume referred to in the title, now issuing from the bindery of the State Printing Office, Sacramento, contains heliogravure reproductions of the late Director KEELER'S photographs of nebulæ and star clusters made with the Crossley reflector. Other contents are a description of the Crossley reflecting telescope by Director KEELER, a list of the nebulæ and clusters photographed, a catalogue of 744 new nebulæ discovered on the negatives, and new determinations of the positions of the nebulæ previously known in the regions of the sky covered. It is hoped that the regular correspondents of the Lick Observatory can be supplied promptly with copies. The cost of the volume has been unusually high on account of the expensive processes and materials employed. There are seventy-one full-page heliogravure reproductions, printed by hand-press on suitable paper. The price of the volume has been fixed at $5.00, postage paid. Subscriptions may be sent to the University Press, Berkeley, California.

W. W. CAMPBELL.

MT. HAMILTON, CAL., January 4, 1909.

GENERAL NOTES.

Astronomical Papers.—At the meeting of the Astronomical and Astrophysical Society of America, held at Put-in-Bay, Ohio, August 25-28, 1908, a programme consisting of thirty-one papers was presented. Titles of these papers, and abstracts from most of them, were printed in *Science* for December 11th. Titles and abstracts of twelve papers upon astronomical subjects presented before Section A of the American Association for the Advancement of Science, at the Baltimore meeting during convocation week, were printed in *Science* for January 22, 1909.

Notes from "Science."—The Paris Academy of Sciences has divided the La Lande prize between Professor W. L. Elkin, director of the Yale Observatory, and Dr. F. L. Chase, assistant astronomer in the observatory, for their papers on "The Parallax of 163 Stars." Mr. M. F. Smith, assistant in the observatory, was given honorable mention in the award.

Professor George Davidson, head of the geographical department of the University of California, has been presented with the Charles P. Daly medal of the American Geographical Society.

The Vienna Academy of Sciences has elected M. Henri Poincarė, the eminent mathematician, to honorary membership. Among the corresponding members elected is Dr. G. H. Darwin, Plumian professor of astronomy at Cambridge.

Dr. H. Morize has been appointed director of the Rio de Janeiro Observatory in the room of the late Professor L. Cruls.

M. Charles E. Stuivaert, associate astronomer in the Royal Observatory of Belgium, died on November 18th, at the age of fifty-seven years.

The Royal Society has given to Cambridge University the stellar spectroscopic equipment which has been in the care of Sir William Huggins since 1871. It consists of the following instruments: A refracting telescope with an object-glass fifteen inches in diameter and fifteen feet in focal length, to which is attached a spectroscope arranged for both visual and photographic work; and a Cassegrain reflecting telescope with a mirror made of speculum metal, eighteen inches in diameter and about seven feet in focal length, to which a spectroscope is attached with optical parts made of Iceland spar and quartz, for photographing the ultra-violet spectrum of stars. These two telescopes are mounted equatorially on a single polar axis, in such a way that they can be moved independently in declination. They are at present installed in a dome about twenty feet in diameter, in Sir WILLIAM HUGGINS's garden at Tulse-hill. The telescopes and the equatorial mounting were made by Sir HOWARD GRUBB, in Dublin, and the spectroscopes by Messrs. TROUGHTON and SIMMS. The instruments are described as being in excellent working order, and would only require such insignificant changes as are usually needed in passing from one series of observations to another in the ordinary work of an observatory, but a suitable dome will have to be provided for the proper installation of the telescopes.

Lord ROSSE bequeathed £1,000 to Trinity College, Dublin, for the science schools. His telescope and scientific instruments are left to his oldest son, with £2,000 for their upkeep.

George W. Hough.[1]—By the death of Professor GEORGE W. HOUGH, on New Year's day of the present year, astronomy and meteorology lost a follower who has made contributions of permanent value to both sciences. Those who enjoyed the privilege of acquaintance with Professor HOUGH will agree that he well deserved the tribute paid to him by a distinguished astronomer, who, in a personal letter, says: "He was a rare man among astronomers in giving to astronomical work good sound common sense. He never found a mare's nest, and never went into idle speculations where the maximum conclusions are deduced from the minimum facts. For more than thirty years I have admired his honesty and good faith in all scientific work. So far as I know, there is nothing he ever had occasion to correct or retract, which is saying a good deal in these days."

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[1] This brief account of Professor HOUGH's life is taken in large part from a sketch to appear in the *Monthly Weather Review*, which was sent to me in advance of publication.—R. G. AITKEN.

George Washington Hough was born in Montgomery County, New York, on the 24th of October, 1836; graduated B. A. from Union College in 1856; married in 1870; and died at his home in Evanston, Ill., on the first day of the current year.

Upon leaving college, Professor Hough taught for a year or so in the schools of Dubuque, Iowa; and pursued graduate work in Harvard College; so that his serious astronomical work did not begin until 1859, when he accepted appointment as assistant astronomer in the Cincinnati Observatory, then justly celebrated on account of its powerful glass and its able director, General O. M. Mitchell. At the end of his first year in Cincinnati came promotion to the directorship of the Dudley Observatory, where he succeeded the late Dr. B. A. Gould.

His fourteen years of residence in Albany (1860-1874) constitute a period during which his inventive genius was at its best. It was here that his printing barometer was brought out in 1865. This instrument gives two graphical records of the barometric height, on different scales, and prints with a type-wheel the reading of the barometer, at the end of each hour, to the nearest thousandth of an inch. It was about this time, also, that his self-recording thermometer and anemograph were devised. In the *Annals of the Dudley Observatory*, Vol. II (Albany, 1871), may be found a description of these instruments, together with a continuous hourly record from the printing barograph for a period of five years. In 1871 he perfected his now well-known printing chronograph.

Examination of the reports of the Dudley Observatory during these years shows that Professor Hough, in addition to his interest in meteorology, gave full attention to the astronomical work of the observatory, carrying on meridian-circle observations of almanac stars, of planets and of asteroids, and also zone observations, and observations with the equatorial telescope. It is of interest to note that as early as 1867 he began to turn his attention to double stars, stating in his report for that year his intention of remeasuring the closer pairs from Struve's catalogue as opportunity offered.

An interval of five years, between 1874 and 1879, was devoted to commercial pursuits. The latter of these dates marks his appointment to the directorship of the Dearborn Observatory, a post which he was destined to honor for the succeeding thirty years. The year 1879 also marks the beginning of a micrometric study of the surface of the planet *Jupiter,* which within a few years made him a leading authority upon this subject. Except for the year 1888, when the Observatory was moved from Chicago to Evanston, his study of *Jupiter* was uninterrupted to the end of his life, and his papers giving the results of this work are commended to students of planetary markings.

Professor HOUGH's interest in double stars became more active when he secured the use of the fine 18½-inch Dearborn telescope, which already had an honorable record in work of this character. Beginning with the year 1881, he gave a portion of his time to the discovery of new double stars as well as to the measuring of pairs already known. So successful was he in this work that 648 new pairs stand to his credit. As many of these are exceedingly close and difficult, and a very large percentage of them sure to prove binary systems, they well merit the attention of astronomers. Quite recently Professor ERIC DOOLITTLE, of the Flower Observatory, has remeasured all the Hough stars, and published his results, together with the earlier ones by HOUGH and other observers, in a general catalogue,—a well-deserved compliment to the value of HOUGH's work. It may be added that one of his discoveries, Ho 212 = 13 *Ceti,* has been shown to revolve in a period of seven and one half years—a period shorter than that of any other known visual binary except δ *Equulei.*

On the removal of the Dearborn Observatory to Evanston in 1888, a new dome was to be designed. That fine mechanical sense which had already enabled him to do much for the instrumental side of his science now led him to invent a roller-bearing dome and a most excellent observing chair, which have been copied in many important observatories.

Class-room teaching Professor HOUGH never considered his chief function. Yet no student ever left his lecture with the recollection of an unkind word or of an explanation that was not clear.

Sham and ostentation were foreign to his nature. In simplicity of life, accuracy of scholarship, singleness of purpose, and kindliness of heart, his friends will all remember him as a worthy example.

The Total Solar Eclipse of May 8, 1910.—The following data were published by A. M. W. Downing, in *Monthly Notices of the Royal Astronomical Society,* No. 9, **68,** 664, 1908:—

This eclipse is observable in Tasmania, though not under very favorable conditions, owing to the Sun's low altitude at the time of totality.

The particulars for Hobart are given on page 444 of the *Nautical Almanac* for 1910. It will be noticed that the Sun sets before the ending of the partial phase of the eclipse.

Port Davey, in the southwest of Tasmania, is, however, a more favorable station from which to observe the total phase of this eclipse, the duration of totality there being half a minute longer than the duration at Hobart. Some particulars of the eclipse as seen from Port Davey are given, as an example of eclipse calculations, on page 590 of the *Nautical Almanac* for 1910. For the convenience of observers these are reproduced here, and some additional particulars added.

Port Davey. Long. 146° 0′ E. Lat. 43° 22′ S.
Standard Mean Time (10^h East).

						Angle from	
		d	h	m	s	North Point.	Vertex.
First contact	May	9	3	4	2	247°	99°
Total eclipse		9	4	11	55	52	272
		9	4	15	25	267	127
Sun sets		9	5	8			

With the existing errors of the lunar tables, the predicted times for the phases of the eclipse given above will be several seconds too late. It may be useful, therefore, to add the intervals in time from the instant when the cusps subtend a given angle at the Sun's center to the commencement of totality.

Angle of Cusps.	Time before commencement of totality.
90°	42^s
60	16
45	9
30	4
15	1

The Sun's altitude at the time of totality is 8°.

Note on the Life and Services of John Tebbutt.—An Australian correspondent has sent me a copy of the *Sydney Morning Herald* for October 17, 1908, containing an appreciative review of the life and astronomical work of Mr. JOHN TEBBUTT, of Windsor, New South Wales. As explained in the review, which is published below, Mr. TEBBUTT is a private astronomer. His services have been continuous and exceedingly fruitful for several decades. In this connection it should not be forgotten that contributions from the southern hemisphere, where observers are scarce, have a value much greater than similar ones from the northern hemisphere, where active observatories exist in abundance. This is especially true of comet observations. For long stretches of time Mr. TEBBUTT was really the only active and accurate observer of these objects in the southern hemisphere. His energy and enthusiasm are worthy of wide recognition from astronomers in all countries, and the writer expresses the hope that Mr. TEBBUTT's activity has not ceased. W. W. C.

Mr. JOHN TEBBUTT has just issued a most interesting popular account of his astronomical work at Windsor from 1853 to the end of 1907. This is a remarkable instance of a lifelong devotion to science, and though Mr. TEBBUTT has his reward in the knowledge of much fine work accomplished, and incidentally in his high reputation as an astronomer, too few of us realize the importance of the contributions to science New South Wales has thus been able to make. The sketch now issued may do something to remove an ignorance which is not altogether the fault of the man in the street, for astronomical papers are not as a rule published in a form accessible and intelligible to him. Mr. TEBBUTT's grandfather arrived in Sydney about the close of 1801, traveling, since there was no other way, in the convict ship "Nile," on which was the celebrated MARGARET CATCHPOLE. The family shortly after their arrival settled in the Hawkesbury district, and carried on a general business at Windsor from 1829 to 1843. It was here that JOHN TEBBUTT was born in 1834. After a time the local Church of England clergyman undertook his education, and brought him up on sound classical fare, but without neglecting mathematics and the "use of globes." Mean time, the family had acquired the estate known as the Peninsula, and a house had been erected in 1845. Mr. TEBBUTT was still a boy when he first felt the fascination of astronomy, and he tells us he made his first observation—that of a comet—in 1853, when he possessed only a marine telescope and a celestial atlas. The brother of Mr. STILES, the clergyman, had been a midshipman in the Royal Navy, and he suggested the purchase of a sextant and a book on navigation. There was in the house a Scotch eight-day clock, with seconds pendulum, which is still going. In the early days Mr. TEBBUTT regulated the clock by sextant observations, and also by transits of the Sun and stars over two fixed plumb-lines adjusted at a considerable distance from each other and in the plane of the meridian. He had read that the Sun rotated in about twenty-five days, and proceeded to verify this in an ingenious manner. This led him to make his first astronomical publication—in the *Sydney Morning Herald* of 1854. In 1857 there was a total eclipse of the Sun. It happened that Windsor was almost at the center of the Moon's dark shadow. In 1858 comet Donati appeared, and with the rough instruments at his disposal Mr. Tebbutt calculated its orbit. Another comet appeared in 1860, and Mr. Tebbutt's orbit for this, calculated from sextant observation, was confirmed by our first Government Astronomer, Rev. W. Scott, who had a small equatorial at Sydney. The year 1861 was notable, for then for the first time a new comet was discovered in Australia. Mr. Tebbutt detected it on May 11th, but it did not become visible in the northern hemisphere until near the end of June. At the time it was first noticed Tebbutt's comet was about 124,000,000 miles away, and as it showed no tail (moving in the line of sight) it was a difficult object. Subsequently it showed a tail, stretching a third of the way round the heavens, and it was one of the most brilliant comets Sir John Herschel had ever seen. Full justice was done, we are glad to know, to Mr. Tebbutt's claims for priority in discovery. This comet has a period of some 409.4 years, so that it will not come back until about 2271. At this time Mr. Tebbutt obtained an excellent refracting telescope. At the close of 1863 he erected a small observatory with his own hands—down to the bricklaying and slating. A two-inch transit instrument was added to the equipment. A small octagonal tower was built for the telescope. Meteorological observations had already begun. Mr. Tebbutt decided to devote himself to occultations of stars by the Moon, to eclipses of *Jupiter's* satellites, and positions of comets. There were, of course, no cable messages in those days, and his work was therefore quite isolated. In 1867 a memorable flood occurred and the observatory was almost completely submerged though the instruments had been removed in time—the only flood which has entered the buildings up to the present time. In 1869 Windsor was placed in the list of observatories in the *British Nautical Almanac*—a well-deserved recognition. A larger telescope was added in 1872, and next year Mr. Tebbutt was elected F. R. A. S. A great event was the observation of the transit of *Venus* in 1874—at a temperature of 109°.5 in the shade. A more substantial observatory was built in 1879, and a Grubb eight-inch equatorial added in 1886. An impetus was given to local astronomical work in 1895 by the establishment of a New South Wales branch of the British Astronomical Association, and of this Mr. Tebbutt was first president. Mean time Mr. Tebbutt's systematic work had been carried on through all these years with the utmost devotion, and to the great advantage of science; his material in fact early earned a reputation for remarkable accuracy, and was relied on by the most eminent of European calculators. This work drew to a close in 1904, when Mr. Tebbutt had attained his seventieth year. It had included some 1,400 occultations of stars by the Moon, many valuable measurements of double stars, 120 papers in the

Monthly Notices, many other contributions to astronomical journals, and much work on cometary orbits—Mr. TEBBUTT has discovered several comets besides the notable one of 1861 referred to. Such single-souled labor is not easy to parallel, and it must be remembered that most of it was carried out without any assistance from others, and without that sympathy and intercourse which does so much to lighten the toil of scientific investigation.—W. G. P.

NEW PUBLICATIONS.

Annals of the Astronomical Observatory of Harvard College.

Vol. LIV, A catalogue of 36,682 stars fainter than the magnitude 6.50 observed with the 4-inch meridian photometer, forming a supplement to the revised Harvard photometry. EDWARD C. PICKERING. Cambridge. 1908. 4to. 280 pp.

Vol. LVII, Part II, Comparison stars for 252 variables of long period. LEON CAMPBELL. 1908. 73 pp.

Vol. LIX, No. 2, Photographic photometry on a uniform scale. EDWARD S. KING. 29 pp., with one plate.

Vol. LX, No. 9, A catalogue of photographic charts of the sky. 20 pp.

Vol. LXIV, No. 1, Observations with the meridian photometer during the years 1902 to 1906. 32 pp.

Vol. LXIV, No. 2, The variable star SS *Cygni,* 213843. LEON CAMPBELL. 20 pp., with one plate.

Vol. LXIV, No. 3, SHÖNFELD's comparison stars for variables. 34 pp.

Annuaire pour l'an 1909, publié par le Bureau des Longitudes. Paris. 16mo. vi + 710 + A 116 + B 57 + C 11 + D 47 pp. Paper. Price, 1 fr. 50 c.

Anuario del observatorio astronómico nacional de Tacubaya para el año de 1909. México. 1908. 16mo. 610 pp. Paper.

Annuario astronomico pel 1909 Publicato dal R. Osservatorio di Torino. Torino. 1909. 8vo. 93 pp. Paper.

Astronomiska Iakttagelser och Undersökningar å Stockholm's Observatorium. Band 9. Uppsala and Stockholm. 1908. 4to. Paper. N : r. 1, Analytische Merkmale des Dreikörper-Problems von KARL BOHLIN. 72 pp. N : r. 2, Integral-Entwickelungen des Dreikörper-Problems von KARL BOHLIN. 141 pp., mit 11 Tafeln und 3 Textfiguren.

Jacoby, Harold. Rutherfurd photographs of stars surrounding 59 *Cygni*. Contributions from the Observatory of Columbia University, No. 25. New York. 1908. 8vo. 23 pp. Paper.

Katalog der astronomischen Gesellschaft. Zone — 14° bis — 18°. Catalogue of 8,824 stars between 13° 50′ and 18° 10′ of south declination, 1855 for the equinox 1900 from observations with the Pistor and Martins transit circle at the United States Naval Observatory, Washington, D. C., during the years 1894 to 1905, by A. N. Skinner. Leipzig. 1908. Folio. 23 + 180 pp. Paper.

Klinkenberg, L. M. Die Greenwich-Deklinationsbestimmungen von Polaris, 1851-1905. Proefschrift. Rotterdam. 1908. 4to. 84 pp. Paper.

Poor, Charles Lane. An investigation of the figure of the Sun and of possible variations in its size and shape. Contributions from the Observatory of Columbia University, New York, No. 26. Reprinted from the Annals of the York Academy of Sciences, Vol. XVIII. August, 1908. 8vo. 385-424 pp. Paper.

Publications of the Astronomical Laboratory at Groningen. Groningen. 1908. Folio. Paper. No. 19, The proper motions of 3,300 stars of different galactic latitudes, derived from photographic plates prepared by Professor Anders Donner, measured and discussed by Professor J. C. Kapteyn and Dr. W. De Sitter. xiii + 42 + T 115 pp. No. 21, A determination of the apex of the solar motion according to the method of Bravais, by H. A. Weersma. 74 + xxxi pp.

Publications of the Lick Observatory. Vol. VIII, Photographs of nebulæ and clusters, made with the Crossley reflector by James Edward Keeler. Sacramento. 1908. 8vo. 46 pp., with 70 plates. Cloth. Price, $5.00.

Publications of the Washburn Observatory of the University of Wisconsin. Vol. XII. Madison. 1908. 4to. 317 pp. Paper. Part I, Proper motions of faint stars, by George C. Comstock. Part II, Meridian observations of comparison stars, by Albert S. Flint.

Recherches astronomiques de l'observatoire d'Utrecht III, The variable star U *Geminorum,* by J. VAN DER BILT. Utrecht. 1908. 8vo. 115 pp., with 29 plates. Paper.

SCHŒNBERG, E. Die Polhöhe der Jurjewer (Dorpater) Sternwarte aus Talkott-Beobachtungen mit dem Repsoldschen Zenitteleskop. Publikationen der Kaiserlichen Universitäts-Sternwarte zu Jurjew (Dorpat). Band XXI, Heft 1. Dorpat. 1908. Folio. 33 pp., with one plate. Paper.

TEBBUTT, JOHN. Astronomical Memoirs. Sydney. 1908. 8vo. 132 pp., with 5 illustrations.

Veröffentlichungen des königlichen astronomischen Rechen-Instituts zu Berlin. No. 36, Genäherte Oppositions-Ephemeriden von 29 kleinen Planeten für 1909 Januar bis 1909 Juli. Unter Mitwirkung mehrerer Astronomen, insbesondere der Herren A. BERBERICH und P. V. NEUGEBAUER, herausgegeben von J. BAUSCHINGER. Berlin. 1909. 8vo. 12 pp. Paper.

WOLFER, A. Die Häufigkeit und heliographische Verteilung der Sonnenflecken in Jahre 1907; Vergleichung mit den Variationen der magnetischen Deklination. Die partiale Sonnenfinsternis vom 28 Juni, 1908, beobachtet in Zürich. Forstsetzung der Sonnenfleckenliteratur. Astronomishe Mitteilungen gegründet von Dr. RUDOLF WOLF. Nr. XCIX. Zürich. 1908. 8vo. 32 pp. Paper.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD AT CHABOT OBSERVATORY, OAKLAND, CAL., SATURDAY, JANUARY 30, 1909.

President **BURCKHALTER** presided. The minutes of the meeting held November 28, 1908, were approved.

The Committee on Location was authorized to procure a place for holding the annual meeting, March 27, 1909.

The following was elected to membership:—

The Chief Astronomer, Department of Interior, Ottawa, Canada.

President **BURCKHALTER** announced the appointment of the following committees:—

Auditing Committee: F. R. **ZIEL** (Chairman), J. A. **LANGSTROTH**, W. H. **LOWDEN**.

Nominating Committee: **JOSÉ COSTA** (Chairman), **OTTO VON GELDERN**, J. H. **MOORE**, W. H. **SMYTH**, B. L. **HODGHEAD**.

Adjourned.

MINUTES OF THE MEETING OF THE SOCIETY, HELD IN CHABOT OBSERVATORY, OAKLAND, CAL., JANUARY 30, 1909, AT 8 O'CLOCK P.M.

President **BURCKHALTER** presided. The minutes of the November, 1908, meeting were approved.

There being no further business, the President introduced Professor **ALEXANDER** G. **MCADIE**, official in charge of the U. S. Weather Bureau in San Francisco, Cal., who delivered an interesting lecture on "Mountain Sites for Observatories." The lecture was illustrated by lantern slides.

The second lecture of the evening was to have been delivered by Professor T. J. J. **SEE**, Director of the Naval Observatory, Mare Island, Cal. Professor **SEE** was unfortunately unable to be present because of an attack of appendicitis. His lecture was read by the Secretary. It was entitled, "The Laws of Cosmical Evolution and the Expansion of the Solar System beyond *Neptune*." The lecture was illustrated by lantern slides. Professor **SEE**'s paper announced for the first time his new theory of cosmical evolution in which was given his argument for the existence of one or more trans-Neptunian planets.

Adjourned.

OFFICERS OF THE SOCIETY.

Mr. Charles Burckhalter...*President*
Mr. W. W. Campbell...*First Vice-President*
Mr. G. E. Hale...*Second Vice-President*
Mr. F. Morse...*Third Vice-President*
Mr. R. T. Crawford (Students' Observatory, Berkeley)....................*Secretary*
Mr. R. G. Aitken (Mount Hamilton, Cal.)..............................*Secretary*
Mr. D. S. Richardson...*Treasurer*

Board of Directors—Messrs. Aitken, Burckhalter, Campbell, Crawford, Crocker, Cushing, Galloway, Hale, Morse, Richardson, Townley.

Finance Committee—Messrs. Cushing, Crocker, Aitken.

Committee on Publication—Messrs. Townley, Maddrill, Moore.

Library Committee—Messrs. Crawford, Townley, Einarsson.

Comet-Medal Committee—Messrs. Campbell (ex-officio), Perrine, Townley.

NOTICE.

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January of each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary at Berkeley ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, S. D. Townley, Stanford University, California.

The Secretary at Berkeley will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage.

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, and November, and at the Lick Observatory on the last Saturdays of June and August. Members who propose to attend the meetings at Mount Hamilton should communicate with the Secretary at Berkeley, in order that arrangements may be made for transportation.

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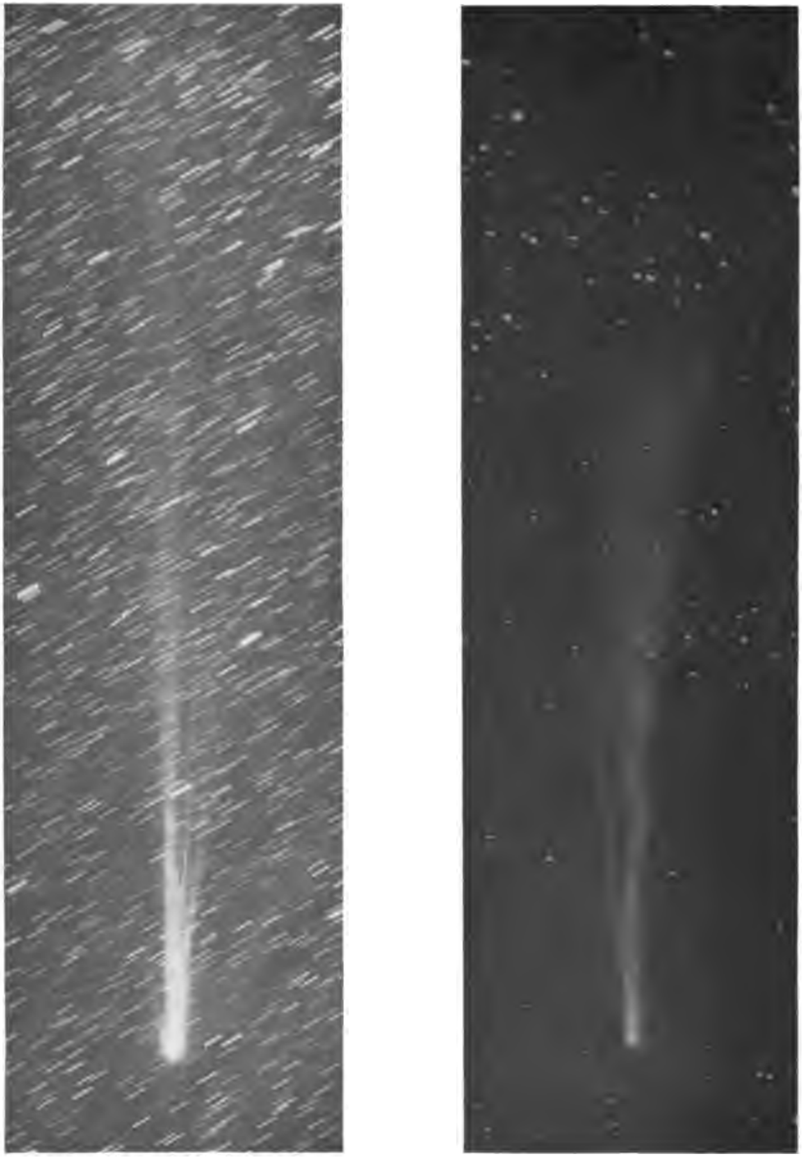

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Vol. XXI. San Francisco, California, April 10, 1909. No. 125

ADDRESS OF THE RETIRING PRESIDENT OF THE SOCIETY, IN AWARDING THE BRUCE MEDAL TO DR. GEORGE WILLIAM HILL.

By Charles Burckhalter.

The eighth award of the Bruce Gold Medal of this Society has been made to Dr. George William Hill.

To those having understanding of the statutes, and the method governing the bestowal of the medal, it goes without saying that it is always worthily bestowed. The statutes require that, for each medal awarded, eminent astronomers,—the directors of six of the greatest observatories in the world,—shall be asked each to nominate three astronomers worthy to receive the Bruce Medal "for distinguished services to astronomy." The six observatories have always been Harvard, Lick, and Yerkes in this country, and Berlin, Greenwich and Paris in the Old World. From the nominations thus made the Directors of this Society, by ballot, choose the Medalist.

The list of names of those whom we have thus honored, and in honoring them we have honored the Society, is an inspiring one—all household names in astronomy. The first award was to Simon Newcomb, a native of Nova Scotia; the second to Arthur Auwers, a German; the third to Sir David Gill, an Englishman; the fourth to Giovanni Virginio Schiaparelli, an Italian; the fifth to Sir William Huggins, an Englishman; the sixth to another German, Hermann Carl Vogel; the seventh to Edward C. Pickering, the first native-born American to receive the medal; and the eighth to our present medalist, also an American. The Bruce Medal, like astronomy, knows nothing of boundaries.

In a paper in the *Popular Science Monthly* for October, 1908, Professor PICKERING calls attention to the fact that there are only six Americans who are members of three or more of the seven leading National Scientific Societies (England, France, United States, Russia, Germany, Austria and Italy) and of these six, three are astronomers; and I wish to add, of the three astronomers our medalist is one. Professor PICKERING also points out that every living Bruce Medalist belongs to three or more of these societies.

Although this is but the eighth award of the medal, so great is the care taken in its bestowal, and with such wisdom have the selections been made, that the Bruce Gold Medal is already recognized as one of the greatest honors that can be conferred upon an astronomer.

The statutes for the bestowal of the Bruce Medal require the President of the Society at this meeting to "Announce the award and the reasons for making it." Let me here say that no adequate review of Dr. HILL's work can be comprised in this address; in his "Collected Mathematical Works" there are eighty-four memoirs, every one of which shows the master mind. And I wish at once, frankly, to confess my inability to give an opinion of the value of Dr. HILL's services to astronomy, and in this, your President feels that he is but one of a large company. Only specialists in celestial mechanics are competent to appreciate and appraise the utility and importance of his monumental achievements; the opinions of those intellectual giants who are his colaborers, alone can reflect to us a true estimate of their value.

Professor NEWCOMB in his "Reminiscences of an Astronomer" says of Dr. HILL that "he will easily rank as the greatest master of mathematical astronomy during the last quarter of the nineteenth century." Wedded to his chosen field of labor, he worked, year after year, scarcely known to the public, patient, underpaid, his ability appreciated by only a few of his colleagues, but content that he could advance his beloved science. Speaking of this time, NEWCOMB says of him: "Here was perhaps the greatest living master in the highest and most difficult field of astronomy, winning world-wide recognition for his country in the science and receiving the salary of a department clerk."

The list of honors conferred upon our medalist by institutions of learning in this and foreign countries is a long one, among which I may mention the Damoiseau prize, of the Paris academy, the degree of Doctor of Laws, by Cambridge University, England, and the gold medal of the Royal Astronomical Society. Our own recognition is, of necessity, somewhat tardy, for he has been nominated again and again by eminent astronomers, for the honor of the Bruce Medal.

I have said that only an expert can rightfully weigh such work as that of our medalist. Such an one is Mr. HENRI POINCARÉ, who has written, in French, an introduction to the "Collected Mathematical Works of George William Hill." From this, the following abstract has been prepared by Dr. R. G. AITKEN, of the Lick Observatory:—

"Dr. HILL," says POINCARÉ, "is one of the most original figures in the American scientific world. Throughout all his works and his calculations he has remained a stranger to the feverish life that has troubled others; he has conducted his researches in isolation, formerly in the bureau of the Nautical Almanac, more recently at his quiet home in the Hudson Valley. This reserve, I was about to say this shyness, has been a happy circumstance for science, for it has permitted him to carry his ingenious and patient researches to their conclusion without suffering distractions from the constant accidents of the world outside."

Dr. HILL was born in New York, March 3, 1838. His father, an Englishman, came to America in 1820 at the age of eight; his mother, of an old Huguenot family, transmitted to him the traditions of the earliest colonists of America. He passed his infancy at the farm at West Nyack, about twenty-five miles from New York, which his father bought shortly after HILL's birth.

"He always loved his home, he returned to it as often as he could, and when he resigned from the Nautical Almanac Office he made his permanent home there, and there he pursues his studies in tranquility, avoiding, as far as possible, even journeys to New York."

At the age of seventeen he entered Rutger's college, New Brunswick, New Jersey, where his professor in mathematics was Dr. STRONG, a friend of BOWDITCH, the translator of "Laplace's Mécanique Céleste."

"Dr. STRONG was a man of traditions, one who praised the bygone times; for him EULER was the god of mathematics, and after EULER, decadence began; it is true that this is a god one may worship with profit. With rare exceptions Dr. STRONG's library was pitilessly closed against all books of later date than 1840. Happily, excellent works on celestial mechanics were written prior to 1840, for example, those of LAPLACE, LAGRANGE, POISSON, and PONTÉCOULANT. These were the masters by whom HILL was introduced to the rudiments of the science."

Receiving his degree in 1859 he went to Harvard to continue his mathematical studies, but in the spring of 1861 joined the Nautical Almanac staff and spent the next thirty years of his life in that service. Those were the most fruitful years in point of scientific productions. At this time the Nautical Almanac Office was at Cambridge, Mass., under the direction of Professor RUNKLE, the founder of the *Mathematical Monthly,* in which prizes were proposed for the solution of mathematical problems. "One of the first articles published," says POINCARÉ, "revealed the hand of a master and easily gained the prize. It dealt with the functions of LAPLACE and the figure of the Earth. The author was Mr. HILL, who was just about to leave college."

HILL continued to make many contributions on various mathematical subjects, generally, however, connected in some way with celestial mechanics, to the *Mathematical Monthly,* and to the *Analyst* and similar journals.

While the Nautical Almanac Office remained in Cambridge under RUNKLE, HILL's work for it was done at his home in West Nyack. But, in 1877, when NEWCOMB assumed charge, "he wished to undertake a colossal task, the reconstruction of the tables of all the planets; Mr. HILL's part in this task was the most difficult; it was the theory of *Jupiter* and *Saturn,* with which he began to busy himself about 1872." He could not well carry on this work away from his chief and his colleagues, so was obliged to leave his home, a sacrifice readily made in view of the importance of the work. But he returned to his home when the bureau was moved to Washington.

In 1892 he resigned from the Nautical Almanac. For a short time thereafter he held a professorship in Columbia University, but he did not continue in this position long, and since then "has lived alone with his books and his souvenirs."

Inspection of the tables of contents in the four volumes of his "Collected Mathematical Works," published by the Carnegie Institution, of Washington, shows what a wide range his investigations took, in every department of celestial mechanics.

HILL's greatest work, according to all competent judges, consists in his researches on, and contributions to, the lunar theory. This account of it is based on POINCARÉ's introduction. He says it is the work to which HILL "devoted all the originality of his genius."

To comprehend HILL's work, POINCARÉ gives a brief account of the state of the theory when HILL began his work. Two great works on this subject had been completed at this time—HANSEN's and DELAUNAY's—each exhibiting the results of the highest sagacity and of extreme patience.

The methods adopted by these two investigators are radically different; HANSEN, who completed his work first, had in mind the purely utilitarian object of computing accurate lunar tables, hence he calculated numerical co-efficients directly and did not trouble himself to find analytical expressions. The tables in actual use to-day are based on HANSEN's calculations, and it is probable that the new theories, more scientific, more satisfactory in their spirit, will not give very different results. DELAUNAY, on the other hand, presented his inequalities in the form of algebraic formulas. "He gives us, then, not only the theory of the Moon, but the theory of any satellite that revolves, or that may revolve about any planet whatever. From this point of view he leaves HANSEN far in the rear. The method which has led him to this result constitutes the most important advance that has been made in celestial mechanics since LAPLACE. To-day, perfected and shortened, it has become an instrument that every one can use, and that has already rendered good service in every part of astronomy."

Unfortunately DELAUNAY's series converges only with excessive slowness and is therefore unsuited to numerical computations. HILL promptly mastered DELAUNAY's theory and made it the subject of various memoirs, but his own method is very different and very original.

Delaunay's series depends on five constants, the eccentricities, the inclination, the solar parallax, and a quantity called *m*, which depends upon the mean motions. If we suppose the first four to become zero, we have a particular solution of the differential equations. This solution will be very much more simple than the general one since the greater part of the inequalities will disappear, the only remaining one being the one known as the "variation."

On the other hand this solution does not precisely represent the Moon's trajectory, but it will serve as a first approximation, since the neglected constants are in effect very small. The choice of *this* first approximation is far more advantageous than the Keplerian ellipse, since for this ellipse the perigee is fixed, whereas in the real orbit it is in motion. The differential equations are at the same time simplified, since, the eccentricity and parallax being zero, the Sun is supposed to describe a circumference of very great radius. Mr. Hill again simplified the equations by judiciously choosing his variables. He does not express them in polar coördinates, but in the rectangular, and this is a great step in advance. Again his variables are not referred to fixed axes, but to axes possessing a uniform rotation, equal to the mean angular motion of the Sun. This was a new simplification, since the time no longer figures explicitly in the equations. "But the most important advantage is the following: For an observer situated on those moving axes the Moon will appear to describe a closed curve, if the eccentricities, the inclination and the parallax are zero. As the differential equations are otherwise rigorous, *this is the first example of a periodic solution of the problem of three bodies* whose existence has been rigorously demonstrated. Recently periodic solutions have assumed capital importance in celestial mechanics. [Poincaré himself is one of the foremost investigators in this branch, if indeed he has an equal.] But our medalist was not content merely to demonstrate its existence; he studied this orbit (or these orbits) in detail, and determined point by point the closed trajectories and calculated the coördinates of these points to many decimals."

Not to follow POINCARÉ's discussion in too much detail, it may suffice here to say that in the further transformations and solutions of these equations, Mr. HILL showed as much daring as originality. His solution involved the consideration of *an infinite number of linear equations.* Not only did he not hesitate to consider these, but he also studied determinants of an infinite order, a thing never before attempted[1] and, happily, his daring was justified by his success.

If we compare his methods with those of DELAUNAY, we shall find that HILL's method by three approximations gave results for the constant of the motion of the lunar perigee correct certainly to thirteen decimals, whereas (to quote from HILL's own paper) "Although DELAUNAY has been at the great pains of computing eight terms of this series, they do not suffice to give correctly the first four significant figures [eight decimals] of the quantity sought. . . . As well as can be judged from induction it would be necessary to prolong the series, in powers of m, as far as m^{27}, in order to obtain an equally precise result."

This will suffice to illustrate the great advance made by HILL in the development of the lunar theory, for the method thus applied to the motion of the lunar perigee may also be applied to the motion of the node. The main difficulties are thus conquered, and the subsequent approximations are relatively easy. Nevertheless practical difficulties still remain, and the field is open for new improvements and new theories. It is unnecessary in this connection to do more than merely to refer to the work of another eminent investigator, Professor E. W. BROWN, who has developed methods of which much is expected.

The inequalities in the lunar motion so far discussed have been those due to the action of the Sun. They are the ones that would be produced if only the Sun, the Moon, and the Earth existed, and they were reduced to material points. But there are other inequalities in the lunar motion, produced in part by the direct action upon the Moon of the other planets, and in part, indirectly, by the disturbing action of these planets upon the motion of the Earth about the Sun. Further, the Earth is not spherical, and its equatorial protuberance exercises an influence upon the lunar motion.

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[1] At least not to Dr. HILL's knowledge at this time. It appears that ADAMS, of Neptunian fame, had been led by his researches to a determinant very nearly identical with the one discovered by HILL. POINCARÉ also refers to a memoir by M. KOTTERITZSCH in *Poggendorf's Annalen,* though he says the method there given had "nothing in common with that of the American Geometer."

In the planetary perturbations of the Moon's motion we may further distinguish between the secular variations and the periodic. Mr. HILL has studied successively the secular acceleration of the mean motion, that of the motion of the perigee, and the influence of the variations of the ecliptic. Nor has he neglected the others, and he has also given careful study to the effect of the oblateness of the Earth and discussed the results of the pendulum determinations of the force of gravity on the Earth's surface.

But the lunar theory did not absorb all of HILL's time or energy. Time and again he turned to investigations dealing with general problems, the general theory of planetary perturbations and special problems in this field. His largest piece of work of this kind is the one undertaken for the Nautical Almanac in connection with and as part of NEWCOMB's "colossal task," referred to above, of the complete discussion of the mutual perturbations of *Jupiter* and *Saturn.*

LAPLACE had entered upon this theory which presents very great difficulties because of what is termed "the great inequality," but his evaluation of the terms of the second order was but a rough approximation. HANSEN was more fortunate, and so arranged his calculations that he was able to estimate the importance of terms he neglected, but he carried out his work completely only in the case of *Saturn*. For *Jupiter* he was content to stop with terms of the first order. We may pass over other memoirs as relatively unimportant until we come to that of LE VERRIER, published in 1876. His theory is indeed complete, but his formulæ are entirely literal, and so arranged that the co-efficients of the inequalities are expressed in terms of corrections to all of the osculating elliptic elements. In practice this leads to excessively long computations and there are apparently some outstanding errors in the formulæ; besides, the tables are not convenient to use. But HILL began his investigations in 1872, before LE VERRIER's results were published and at a time when it was uncertain when they would be published. The tables then in actual use were BOUVARD'S, and these were quite inadequate to meet the needs of astronomers. Having a purely practical end in view, the construction of accurate tables in the shortest possible time, HILL did not seek to develop a new method of investigation. He adopted HANSEN'S, but with modifications that greatly simplified it. So great an amount of computing was involved in this research that Mr. HILL devoted to it seven and a half years of time, being relieved during this time of all routine duties in the Nautical Almanac Office and having the services of an assistant to check by duplicate computations all the more important calculations. The result of this long, and in many ways necessarily tedious work is a splendid volume of theoretical researches, and two volumes of accurate tables, one of the motion of *Jupiter,* the other of the motion of *Saturn.*

The recent progress of celestial mechanics has received and continues to receive Mr. HILL'S constant attention. HANSEN'S and DELAUNAY'S methods, GYLDÉN'S intermediate orbit, the recent developments in periodic solutions of the three-body problem [as presented by POINCARÉ, DARWIN and others], have all been assimilated, and many of them analyzed and discussed in some of his published memoirs.

In his concluding sentence POINCARÉ says: "There is therefore not a single part of celestial mechanics to which he is a stranger, but his chief work, that which will make his name immortal, is his theory of the Moon. It is there that he is not only an able artist, a careful investigator, but an *inventor,* original and profound. I do not wish to say that the methods which he created are applicable only to the Moon. I am well persuaded to the contrary; I think that those who are engaged in study of the minor planets will be astonished at the relief from difficulties they will experience on the day when, having fathomed their spirit, they apply them to this new object. But at present it is for the Moon that they have proved themselves. When they enter upon a wider domain, we ought not to forget that it is to Mr. HILL that we owe so precious an instrument."

We have earnestly hoped that our medalist would be with us this evening, but in a letter to Dr. HALE he said he did not feel strong enough to undertake the journey; therefore, in his absence, I hand to you, Mr. Secretary, for transmission to Dr. HILL, this medal, the highest honor this Society can possibly confer upon an astronomer, and with it I ask you to send the greetings and best wishes of the Astronomical Society of the Pacific, and that we trust the evening of his life may be a long and happy one.

March 27, 1908.

THE LAWS OF COSMICAL EVOLUTION AND THE EXTENSION OF THE SOLAR SYSTEM BEYOND NEPTUNE.

BY T. J. J. SEE.

(Abstract of address delivered January 30, 1909.)

It has long been considered somewhat of a reproach to astronomy that the processes of cosmogony have remained so obscure that definite laws could not be established regarding even the mode of formation of the solar system, while still less was known about the laws for the development of other systems in space. In view of the great progress of the physical sciences since the time of LAPLACE, one is compelled to admit that this criticism of the oldest and most exact of the physical sciences is not wholly unjust and without a certain foundation. Not only has the failure of researches in cosmogony affected astronomy adversely, but it has also narrowed the field of effort in several of the related sciences. This should not, however, occasion surprise among those who study the history of the physical sciences. For as cosmogony depends on the other sciences for its fundamental data, any circumstance which has affected them adversely would also retard the development of cosmogony itself, and *vice versa.*

In addition to the natural difficulties inherent in the development of a complex and dependent science like cosmogony, another has arisen from the demoralization of spirits due to the failures of previous investigators. Those who have labored for years without gaining any satisfactory light on the subject may easily convince themselves that there are no definite laws of celestial development; or imagine that such laws as exist are the outgrowth of various processes,—under repulsive and even explosive forces, as well as under the more familiar attractive force of gravitation. The investigator who has repeatedly failed will readily persuade himself that nature has few, if any, simple laws. This mistaken tendency of many minds is supported and confirmed by the diversity of process apparently required to harmonize discordant phenomena; and the love of novelty thus suggested is often stronger than the love of truth.

Accordingly we have a multitude of theories, most of which have no foundation whatever, and should never have been advanced. The promulgation of theories wholly devoid of foundation is injurious to science and simply aids in the propagation of error. When nothing is known, however, almost any hypothesis which unites and harmonizes phenomena is philosophically justifiable, and may be of some value for the time being; but when means exist for confronting hypotheses with observations, so as to establish contradictions with known phenomena, it is idle and vain to consider any hypothesis which is not free from contradiction.

Heretofore most of the theories of cosmical evolution proposed have been involved in some inconsistency. Indeed, most of them have been directly contradicted by the most obvious phenomena, which admit of no dispute; and yet many of these baseless speculations have continued to circulate even in publications of supposed scientific standing. The vague theories put forth by persons of obscure mind only serve to muddy the stream, so that no one can penetrate beneath the surface; and this leads a considerable body of observers to concentrate attention chiefly on superficial phenomena, which have the double fascination of apparent obviousness and at the same time may be grasped without much labor. But sagacious investigators are not taken in by such palpable deceptions. They are accustomed to look beneath the surface, and realize fully that hard work, extending over many years, is the price which must be paid for discoveries of real value. Until results can be obtained which admit of no contradiction they prefer to wait for more light, and thus have been able to make but few positive advances in cosmogony. In the present discussion we shall refer especially to the solar system, but the principles are obviously applicable to all systems in space, and we need not dwell on the universal character of the theory.

The roundness of the orbits of the planets and satellites has been remarked with wonder and admiration from the earliest ages of science. This remarkable geometrical property of the planetary paths excited the speculative curiosity of ARISTARCHUS and ARCHIMEDES, HIPPARCHUS and PTOLEMY, KEPLER and NEWTON; but while all geometers followed the Greeks in admiring nature's apparent preference for the circle, no one of them attempted to explain this tendency till LAPLACE promulgated the nebular hypothesis in 1796, and accounted for the circularity of the orbits by a rotation of the central mass under gradual acceleration, which would detach the attendant bodies quite gently and set them revolving in orbits approximately circular. LAPLACE's explanation has been generally accepted, and for more than a century it has been universally assumed that the planets and satellites were originally detached from the central bodies which now govern their motions.

Yet as long ago as 1861 BABINET had proposed a mathematical criterion for testing the Laplacian theory, and on applying it to our system found that the classic nebular hypothesis was not confirmed. This criterion rests on the mechanical principle of the conservation of areas, according to which the moment of momentum of a rotating mass is unchanged whatever be the change in radius. Thus if ω be the angular velocity of rotation of a globe of radius r, ω' and r' the corresponding quantities at another epoch; then it follows that

$$r^2\omega = r'^2\omega'$$

On applying this formula to our actual system, with the numerical data adopted in *Astronomische Nachrichten* No. 3992, we find the results given in the accompanying table.

BABINET had applied his criterion to the case of the Earth and *Neptune* and found that the rotation of the hypothetical solar nebula when it was expanded to fill these orbits would not be rapid enough to detach these planets. As his criticism of LAPLACE's theory was destructive and not constructive, it shared the fate common to efforts of this kind, and has been generally lost sight of. Consequently the effect of BABINET's test on current speculative thought was insignificant. The above table gives the best available data for all parts of the solar system, and shows that none of the planets and satellites were ever detached from the central masses which now govern their motions.

Thus we see that the premise underlying LAPLACE's hypothesis, implying that the attendant bodies were detached by rotation, was false, and consequently the reasoning based thereon quite unjustifiable. Therefore his venerable explanation of the roundness of the planetary orbits falls to the ground, and another cause must be sought which admits of verification by means of criteria of acknowledged mathematical rigor.[1]

TABLE SHOWING THE APPLICATION OF BABINET'S CRITERION TO THE PLANETS AND SATELLITES, WHEN THE SUN AND PLANETS ARE EXPANDED TO FILL THE ORBITS OF THE BODIES REVOLVING ABOUT THEM.

Solar System.	Planet.	R_0 The Sun's Observed Time of Rev.	P_0 Observed Period of Planet.	R_c Time of the Sun's Rotation Calculated by BABINET's Criterion.
	Mercury	25.3 days = 0.06267 yrs.	0.24085 years	479 years
	Venus		0.61237 "	1673 "
	The Earth		1.00000 "	3192 "
	Mars		1.88085 "	7424 "
	Ceres		4.60345 "	24487 "
	Jupiter		11.86 "	86560 "
	Saturn		29.46 "	290962 "
	Uranus		84.02 "	1176765 "
	Neptune		164.78 "	2888533 "

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[1] The discussion from here on is substantially identical with that embodied in an article communicated to the *Astronomische Nachrichten* under date of January 1, 1909.

Sub-Systems.	Satellite.	R_0 Adopted Rotation of Planet.	P_0 Observed Period of Satellite.	R_c Time of Planet's Rotation Calculated by BABINET'S Criterion.
Earth	The Moon	1 day	27.32166 days	3632.45 days
Mars	*Phobos*	24.62297 hrs.	7.6542 hrs.	190.62 hrs.
	Deimos		30.2983 “	1193.52 “
Jupiter	V	9.928 “	11.9563 “	64.456 “
	I		1.7698605 days	14.60 days
	II		3.5540942 “	36.900 “
	III		7.1663872 “	93.933 “
	IV		16.7535524 “	290.63 “
	VI		250.618 “	10768.8 “
	VII		265.0 “	11602.4 “
	VIII		930.73 “	61997.2 “
Saturn	Inner Edge of Ring	10.641 hrs.	0.236 day	0.6228 day
	Outer Edge of Ring		0.6456 “	2.383 days
	Mimas		0.94242 “	4.2902 “
	Enceladus		1.37022 days	7.0615 “
	Tethys		1.887796 “	10.822 “
	Dione		2.736913 “	17.751 “
	Rhea		4.517500 “	34.620 “
	Titan		15.945417 “	186.05 “
	Hyperion		21.277396 “	273.06 “
	Japetus		79.329375 “	1580.1 “
	Phœbe		546.5 “	20712. “
Uranus	*Ariel*	10.1112 hrs. (cf. *A. N.* 3992)	2.520383 “	33.714 “
	Umbriel		4.144181 “	65.435 “
	Titania		8.705897 “	176.05 “
	Oberon		13.463269 “	314.83 “
Neptune	Satellite	12.84817 hrs. (cf. *A. N.* 3992)	5.87690 “	141.8 “

Now the planets and satellites could be formed in but one of two possible ways: (1) They might conceivably have been detached from the central masses which now govern their motions, by acceleration of rotation, as supposed by LAPLACE. (2) They might have been original nuclei captured in the midst of the solar nebula, and afterwards gradually built up by the agglomeration of more cosmical dust, while at the same time the orbital motion in this resisting medium would have reduced the major axes and eccentricities of their orbits and thus produced the near approach to perfect circularity now observed in our solar system.

We have, however, just proved, by the application of BABINET'S criterion, based on the law of areas, that these bodies could not have been detached from the central masses about which they now revolve. *Accordingly it follows that they were all captured, and have since had their orbits reduced in size and rounded up under the secular action of the resisting medium formerly pervading the planetary system.*

From this unexpected conclusion there is absolutely no escape; for we may prove this by the following reasoning. The effect of a resisting medium in reducing the major axis and eccentricity of the orbit of the resisted body is fully recognized, and has been known for more than a hundred years. The formulæ for the changes of these two important elements may be reduced to the form

$$\delta a = -\frac{2a^2}{p^2(1+m)}\,[A'\,v + \text{periodic terms}] \;\ldots\; (3)$$

$$\delta e = -\frac{2}{p}\,[Aev + \text{periodic terms}] \;\ldots\ldots\ldots\; (4)$$

where p is the parameter of the orbit, a the semi axis major, e the eccentricity, v the true anomaly, and m the mass of the resisted planet, and A and A' constants. As both of these expressions are negative, it follows that under the secular action of a resisting medium the major axis and eccentricity always decrease. In deriving these formulæ, however, the density of the resisting medium is supposed to increase towards the center, conformable to what is observed in the nebulæ and shown to result from the theory of gases.

LAPLACE himself has discussed this question with characteristic penetration in the *Mécanique Céleste* (Liv. X, ch. VII, § 19). He shows that when the density of the medium, represented by $\Phi\left(\frac{1}{r}\right)$ increases towards the Sun, the semi axis major and eccentricity always decrease; and finally remarks: "Therefore at the same time that the planet approaches towards the Sun, by the effect of the resistance of the medium, the orbit will become more circular." It is surprising that it did not occur to the author of the *Mécanique Céleste* that the roundness of the orbits of the planets and satellites could be explained by a resisting medium quite as easily and simply as by the theory of a rotation which would gently detach these masses and set them revolving in orbits which are nearly circular, especially since the nebular hypothesis itself necessarily implies the existence of such a medium where the planets and satellites now revolve. LAPLACE merely remarks that if the nebula filled the whole of this space the bodies would encounter such resistance as to cause them to fall into the Sun; *but in making this statement he overlooked the fact that most of the nebulous matter did go into the Sun and planets, and it is from this circumstance that the central masses became so preponderant, while the attendant bodies are in all cases so very small.*

During a recent conference with my friend Professor GEORGE DAVIDSON, I mentioned LAPLACE'S proof that a resisting medium had formerly acted against *Jupiter's* satellites I, II, III, to bring about a near approach to commensurability in their mean motions, and thus enable their mutual attraction to establish a rigorous relationship under the influence of this slowly acting cause. This venerable astronomer justly remarked: "LAPLACE had the true cause in sight, but he did not carry it far enough to discover the actual process by which the solar system was formed."

Evidently LAPLACE had not tested his nebular hypothesis by the criterion based on the conservation of areas, afterwards proposed by BABINET, and it simply did not occur to him that the circularity of the orbits pointed unmistakably to the secular action of a resisting medium. As the very existence of a nebula implies resistance to bodies revolving within it, this oversight is the more remarkable; and unfortunately not only was LAPLACE'S reasoning vitiated, but an equally disastrous effect exerted on all other investigations in cosmical evolution for more than a century, because all mathematicians followed the same line of thought, on the false premise that the planets and satellites were detached from the central bodies which now govern their motions.

If in the light of this new theory of the shaping of the orbits under the secular effects of resistance we examine our solar system carefully we shall find many phenomena confirming the former existence of such a medium in our system.

It must suffice here to call attention to but a very few of the numerous survivals of the primordial resisting medium still shown by our system:—

(1) The rapid motion of *Phobos,* the inner satellite of *Mars,* which has been brought down near the planet by resistance, till it now revolves in less than a third of the time of the planet's rotation. It is true that Professor Sir G. H. DARWIN explains this motion of *Phobos* by a tidal retardation of the axial rotation of *Mars,* but in view of the large part undeniably played by the resisting medium in the formation of our system as a whole this explanation will not hold, though a very small part of the observed effect may be traceable to tidal friction.

(2) The famous inequality in the motions of the three inner Galilean satellites of *Jupiter,* which point unmistakably to a resisting medium, as was sagaciously pointed out by LAPLACE in 1796. His remarks on this subject are as valid and convincing as any which could be made to-day.

(3) The observed rapid motion of the inner ring of *Saturn,* which greatly exceeds the axial rotation of the planet. The rings evidently were never detached from the planet, but simply survive out of a much larger mass of cosmical dust which has been absorbed in building up the mass of *Saturn.* All the data in the table relative to BABINET'S criterion bear on this same question.

(4) The general fact that the satellite orbits are so round, and in general rounder and rounder the nearer we approach the planets, confirms the capture of these bodies in a medium which was denser towards these centers. The roundness of the satellite orbits shows that resistance was very effective from *Mars* to *Neptune,* and therefore no doubt throughout our whole solar system.

(5) The retrograde motion of *Saturn's* satellite *Phœbe* and *Jupiter's* eighth satellite is likewise to be explained by the capture of these bodies. Whatever may have been their orig-

inal eccentricities at the time of capture, even retrograde directed bodies could have survived, because the medium against which they revolved was of very slight density at that great distance from the planets. This slight density of the resisting medium at this distance is also indicated by the survival of considerable eccentricities in the orbits of these two satellites. The eccentricity of the orbit of *Phœbe* is given as 0.22, that of *Jupiter* VIII as 0.44, which are certainly anomalous enough to excite our suspicion. It is not by chance that retrograde motion in these two cases is associated with the highest eccentricities observed among all the satellites thus far discovered.

(6) The orbits of the asteroids have been gathered into their present positions mainly by the action of *Jupiter* and of the resisting medium. Originally they were more widely distributed over the whole system than at present; but even now they overlap the orbits of *Jupiter* and *Mars,* and there may be others of still wider range.

(7) The extreme roundness of the orbit of *Neptune* is a clear indication that this planet moved for a long time against a vast amount of nebulous resistance. Therefore it is very improbable that our planetary system terminates with *Neptune. In all probability there are several more planets beyond the present boundary of the system, some of which may yet be discovered.*

(8) The equatorial accelerations noticed on the globes of the Sun and of *Jupiter* and *Saturn* are to be explained by the falling in of matter revolving in vortices about these bodies. As the orbital motion of this matter near these bodies exceeds that depending on the axial rotation, the falling particles necessarily produce an equatorial acceleration. This process may still be going on; at any rate, it has been in progress so recently that the effects still continue.

(9) The solar system was formed from a spiral nebula, revolving and slowly coiling up under mechanical conditions which were essentially free from hydrostatic pressure. And spiral nebulæ themselves arise from the meeting of two or more streams of cosmical dust. The whole system of particles has a sensible moment of momentum about some axis, and

thus it begins to whirl about a central point, and gives rise to a vortex. In the actual universe the spiral nebulæ are to be counted by the hundreds of thousands, if not by the million, and it is evident that they all arise from the automatic winding up of streams of cosmical dust, under the attraction of their mutual gravitation. The two opposite branches of the spiral nebulæ, so often shown on photographs, represent the original streams of cosmical dust which are coiling up and forming gigantic spiral systems.

(10) When the nebula rotates and the coils wind up in such a way as to leave open spaces between the coils, or at least freedom from sensible hydrostatic pressure, the usual result is the development of a system made up of small bodies, such as the planets compared to the greatly preponderant Sun, or the satellites compared to the much greater planetary masses which control their motions. In the solar system where the conditions are accurately known this is proved to have occurred; and it was repeated so many times, always with uniform results, giving a large central mass and small attendant bodies, that the general law for this condition is clearly established.

(11) If the streams so converge that the nebulous mass becomes very concentrated at the center, so as to become a figure of equilibrium under the pressure and attraction of its parts, the nebula may divide into a double star, as I have elsewhere inferred from the researches of POINCARÉ and DARWIN on the figures of equilibrium of rotating masses of fluid.

(12) Now both of these forms of development, depending on variations of the two processes, are abundant in the actual universe, and probably almost all of the apparently single stars are surrounded by systems of planets. At least one fifth of all the stars are estimated to be double or multiple. If we assume the chances of the two forms of development to be equal we may calculate from the preponderance of small bodies actually found in the solar system—eight principal planets, twenty-five satellites (besides our Moon), and 625 asteroids—that the chances of a nebula devoid of hydrostatic pressure producing small bodies is about 2^{658} to 1, or a decillion decillion (10^{66}) to

the sixth power, to unity. This figure is so very large that we shall content ourselves with illustrating a decillion decillion, and for this purpose we avail ourselves of a method employed by ARCHIMEDES to illustrate his system of enumeration. Imagine sand so fine that 10,000 grains will be contained in the space occupied by a poppy seed, itself about the size of a pin's head; and then conceive a sphere described about our Sun with a radius of 200,000 astronomical units (α *Centauri* being at a distance of 275,000), entirely filled with this fine sand. The number of grains of sand in this sphere of the fixed stars would be a decillion decillion (10^{66}). All these grains of sand against one is the probability that a nebula devoid of hydrostatic pressure such as that which formed the planets and satellites will lead to the genesis of such small bodies revolving about a greatly predominant central mass.

This is a very brief and inadequate outline of a few of the leading points in a very large investigation with which I have been occupied. Most of these results were established over six months ago, and I have had opportunity to discuss them with several experienced astronomers. It is hoped that the whole investigation may appear as Volume II of my "Researches on the Evolution of the Stellar Systems"; but it seemed advisable to communicate this brief summary of some of the most interesting points without further delay.

The effect of this work will be to give the theory of the resisting medium the highest importance in all researches relating to the history of the universe. It is very remarkable that the principal secular effects of this cause are exactly opposite to those due to tidal friction as investigated by DARWIN. For while tidal friction usually increases the major axis and eccentricity of an orbit, the resisting medium as regularly decreases both of these elements. In the actual physical universe both causes are at work together, sometimes one influence predominating and then the other. Resisting medium is relatively most effective in a system made up of a large central sun, and small attendant bodies such as the planets of our solar system, and in the systems of satellites dominated by large planets. Tidal friction is most effective in systems made up of two large masses, such as the double stars.

It has seemed important to call attention to the cause of the roundness of the orbits of the planets and satellites, because it appears likely that the criteria now introduced may go far toward clearing up the mystery which has always surrounded the origin of the solar system.

In all the celebrated speculations of the distinguished astronomers who have occupied themselves with the genesis of our solar system, four phenomena have ever been foremost: (1) The great circularity of the orbits; (2) The small inclinations and the common direction of the orbital motion; (3) The smallness of the attendant planets and satellites compared to the large central masses which govern their motions; (4) The regularity and order everywhere found in our system, the distances, masses, and mutual relations of the orbits being such as to secure maximum stability and perpetuity. All these phenomena and many others are now perfectly explained by a simple theory, which also conforms to the laws of spiral development observed in the sidereal universe. A simple and obvious theory which accounts for the known phenomena while all other theories are involved in contradiction, will naturally have a strong claim to acceptance. Indeed we cannot refuse our assent to it without violating the recognized rules of natural philosophy as formulated by NEWTON in the *Principia.*

U. S. NAVAL OBSERVATORY,
MARE ISLAND, CAL., January 30, 1909.

PHOTOGRAPHS OF COMET *c* 1908 (MOREHOUSE).

By A. ESTELLE GLANCY.

From September 19th until December 15th, at which latter date the comet could be followed only long enough to photograph the head, exposures have been made at the Lick Observatory on every favorable occasion. Successful exposures were made on twenty-eight nights. The nights omitted were unfavorable,[1] by reason of too strong moonlight, clouded sky, or high winds. The Crocker photographic telescope was used in this work. This instrument carries two cameras,—a Willard lens of 15.2^{cm} (6.0 inches) aperture and 78.28^{cm} (30.82 inches) focal length, and a Dallmeyer lens of the same aperture and 82.6^{cm} (32.52 inches) focal length. Hence the scale value of the plates taken with the Willard lens is $1° = 1.37^{cm}$ (0.538 inch) and that of the Dallmeyer is $1° = 1.44^{cm}$ (0.568 inch). As soon as the comet had increased sufficiently in brightness to allow of a reasonably short exposure time, it was planned to use the Willard camera for one plate of fairly strong density, and simultaneously to expose in the Dallmeyer camera two plates, each of one half the exposure time with the Willard camera. By this arrangement each camera was made to serve a different purpose. The Willard plate gives a strong image of the general appearance of the comet, including the fainter portions of the tail; the Dallmeyer plates give more truthfully the actual conditions existing at a given time and permit comparisons to determine the motions of condensations or other details of structure in the tail of the comet. It has been recognized for several years that intervals of twenty-four hours are too long to detect the rapid transformations which take place in comets; and a superficial examination of the Willard plates shows this to be particularly true of Comet Morehouse. So different are some of these plates from the one taken on the preceding or the following day that no indications of identity are visible at first sight.

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[1] The number of unfavorable nights was unusually large this year.

Below is a tabulation of the series of Lick Observatory plates, which may be of service to observatories in other longitudes:—

Pacific Standard Time. 1908.	Willard Camera. Middle of Exposure.	Willard Camera. Duration.	Dallmeyer Camera. Middle of Exposure.	Dallmeyer Camera. Duration.
Sept. 19.	10^h 28^m	3^h 0^m	10^h 28^m	3^h 0^m
27.	9 33	1 30	9 33	1 30
27.	12 40	1 30	12 40	1 30
29.	8 56	1 32	8 56	1 32
29.	11 20	1 30	12 8	3 5
29.	12 54	1 29	.. ..	.. ..

Pacific Standard Time. 1908.	Willard Camera.				Dallmeyer Camera.			
	Middle of Exposure.		Duration.		Middle of Exposure.		Duration.	
Oct. 16.	10	20	1	38	9	54	0	47
	..	..	..	..	10	45	0	48
18.	7	58	1	31	7	58	1	31
20.	9	27	2	44	8	45	1	20
	..	..	..	..	10	9	1	20
21.	8	12	2	46	7	30	1	22
	..	..	..	..	8	54	1	21
22.	10	0	2	35	9	19	1	12
	..	..	..	..	10	38	1	20
23.	8	12	2	44	7	28	1	16
	..	..	..	..	8	51	1	26
24.	8	.8	2	44	7	24	1	16
	..	..	..	..	8	47	1	26
25.	8	26	2	21	7	24	1	15
	..	..	..	..	8	50	1	34
26.	7	6	0	36	7	6	0	36
27.	8	50	2	49	8	10	1	15
	..	..	..	..	9	34	1	22
28.	..	..	..	..	8	46	1	1
	..	..	..	..	9	54	1	13
30.	10	25	1	16	10	2	0	30
	..	..	..	..	10	40	0	45
Nov. 10.	6	58	1	5	6	46	0	45
	..	..	..	..	7	20	0	20
11.	6	52	1	32	6	28	0	45
	..	..	..	..	7	16	0	45
12.	7	57	1	54	7	25	0	50
	..	..	..	..	8	26	0	57
13.	7	37	1	42	7	11	0	50
	..	..	..	..	8	3	0	50
14.	7	6	1	40	6	41	0	50
	..	..	..	..	7	33	0	46
15.	7	5	2	10	6	25	0	50
	..	..	..	..	7	38	1	4
16.	7	21	2	42	6	25	0	50
	..	..	..	..	7	31	1	0
	..	..	..	..	8	22	0	40

Pacific Standard Time. 1908.	Willard Camera.				Dallmeyer Camera.			
	Middle of Exposure.		Duration.		Middle of Exposure.		Duration.	
Nov. 17.	7	24	2	43	6	28	0	50
	..	..	..	..	7	22	0	55
	..	..	..	..	8	20	0	53
18.	7	1	1	52	6	30	0	50
	..	..	..	..	7	27	1	0
27.	7	16	1	8	7	16	1	8
28.	7	10	0	44	7	10	0	44
Dec. 10.	6	24	0	29	6	24	0	29
11.	6	27	0	22	6	27	0	22
12.	6	21	0	24	6	21	0	24

The four photographs selected for reproduction were chosen because of their striking appearance. The first and fourth belong respectively to the earlier and later half of the period under observation; the second and third occurring near the middle of the series, demonstrate the changes which may be expected in two days. Since no reproduction by mechanical processes can do justice to the original negatives, a description of these four plates is given to supplement the illustrations.

October 24th.—The comet appears on this date in one of its quieter phases. In the line of strongest expulsion from the head is a long, narrow, dense streamer. On the following side, a broad, heavy streamer extends about 4°.6. On the preceding side, a like streamer of greater density and breadth extends out to 10°. About 3° from the extremity there is a sharp bend in the same direction in which the radius vector[1] is moving. There are two undulations about 2° from the head, and a noticeable bulging at a distance of about 4°.5. Faint line-streamers and one fan-shaped streamer lie outside the main tail. The activity in the head is seen to continue well around on the side toward the Sun.

November 16th.—This plate is one of a group showing very rapid changes. The tail belongs to the type frequently noticed, a central helical structure and outlying, long, narrow streamers. The general direction of the tail is one of continued

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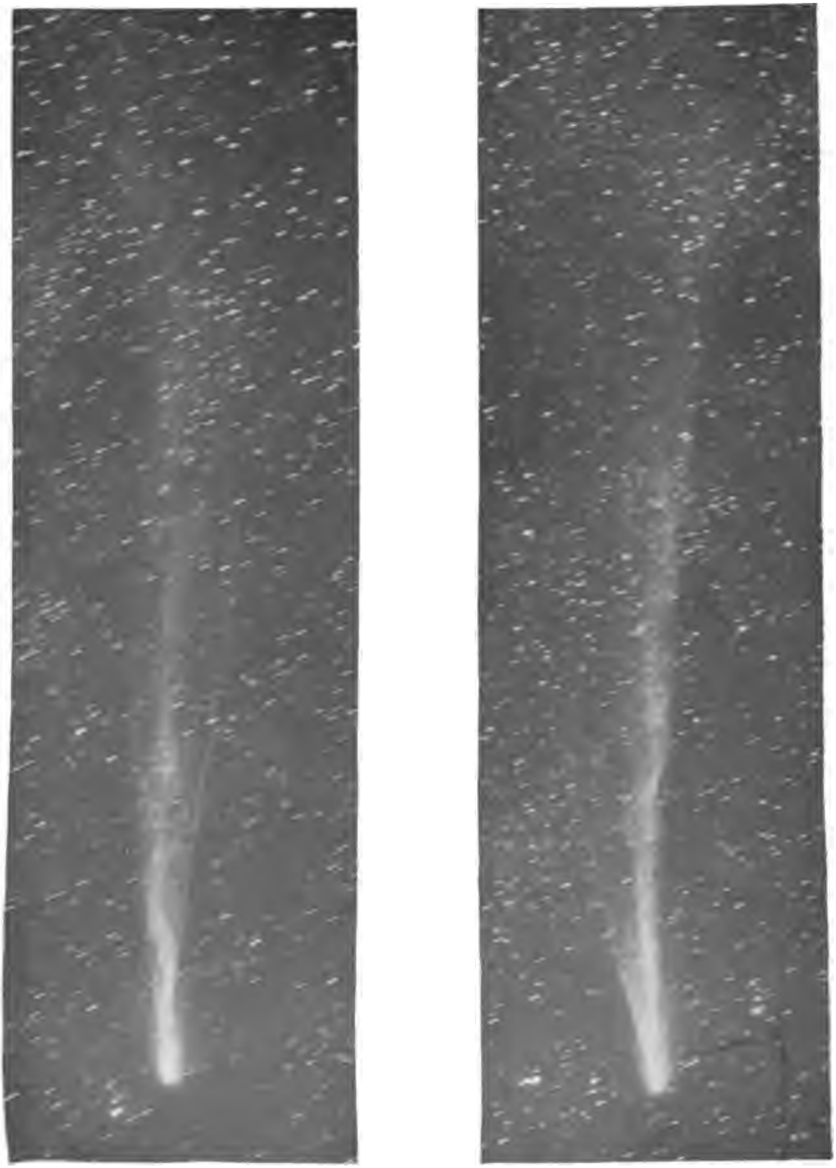
[1] The radius vector is the line joining the Sun and comet. As the comet moves in its orbit this line moves forward also.



Nov. 16, 1908. 7h 21m P. S. T.

Nov. 18, 1908. 7h 1m P. S. T.

COMET C 1908 (MOREHOUSE).

curvature for about 7°. The curvature shows that the tail is lagging behind the radius vector. From 7° to 11° the tail is bent in the opposite direction. The breadth of the tail is due to many diffuse and divergent faint streamers. The matter which is puffed out, as it were, appears to come from the sharp apex of a cone. The clear-cut edges of the cone are outlined by single streamers. Within the cone is a dense, wavy streamer which inclines toward the following side of the cone for about 1°, and then shifts to the opposite side, breaking out into the more pronounced spiral structure. The spiral increases in dimensions until it is finally broken up by the diffusion of the matter composing it. One is reminded of the extraordinary outburst which occurred on October 15th on a larger scale. One fine streamer within the cone appears distinctly severed; the broken ends are thrust far apart. It is worth noticing that the heavy bright streamer whose outer extremity is about 5° from the head, and whose inner extremity appears to be disconnected from the main tail, has appeared within twenty-four hours. No streamer on the plate of November 15th can be identified with it. Short, straight, and more divergent streamers define the boundaries of the tail near the head. The head itself is unusually small, showing both nucleus and coma.

November 18th.—In general appearance this plate resembles that of November 17th, but only in type, for there are no points of identity immediately recognizable. Nearly all the matter composing the tail seems to lie in a well-defined cone with an angle of about 21°. The central portion is very bright and of varying density. The outer parts are composed of many line-streamers, the greater number of these lying on the preceding side. The spiral structure is not so definitely suggested on this plate as on some of the other plates. The source of the densest stream of matter seems to be the well-defined apex of a smaller cone within the cone mentioned above. A large-scale plate might prove this to be an apparent rather than a real effect. The general direction of the tail shows that it is lagging behind the radius vector. On the following side the streamers are few and relatively short, thus leaving a boundary defined by the brightest portions of the tail. On the preceding side the streamers diverge at an unusually large angle from the main tail. On November 17th a similar group of streamers was prominent, but the deviation from the main direction was less. It should be noted that parts of the main tail and the outlying streamers often have corresponding irregularities of structure. The head appears larger than on November 16th, and is active over the greater part of its circumference.

November 27th.—The definition of the photograph is marred by fogging, due to strong moonlight, but what I have called the spiral structure is so well marked that this plate was chosen in preference to other more perfect ones. The tail structure is like that of November 16th. Within the numerous divergent streamers is a narrow cone of luminous matter. About 0°.4 from the head it bulges and the wavy streamers (perhaps there is but one, which is very erratic) appear to shoot out in a conical helix, which is finally dissipated in a broad diffuse flare.

Such a wealth of like data has been gathered by many observers in America and Europe that an unusually complete history of the comet's behavior may be constructed. Certainly no earlier comet has been subjected to such exhaustive observations. Photography finds an important usefulness in comet work, and Comet Morehouse is a remarkably favorable subject for two reasons. In the first place, the orbit plane could scarcely be better situated with respect to the Earth. With an inclination of 140° to the ecliptic, it cuts the equator a little east of the winter solstice, and the point of perihelion passage lies but a little south of the equator. Perihelion passage occurred on December 26th. Hence, from September 1st to December the comet was visible in the northern hemisphere, and during the early part of this period it was a circumpolar object. Five weeks after its disappearance below our horizon it became visible to the southern observers under almost as favorable circumstances, and it can be followed for several months more. Though visually fainter than Comet Daniel 1907, Comet Morehouse photographed more readily. This is due to the fact established by spectroscopic observations here and elsewhere, that the radiations lying in the visual regions of the spectrum (red, orange, yellow, green) are weak and those in the photographic regions (blue and violet) are remarkably strong. Hence this comet, which appears in the visual telescope as an object of little interest, has secured the continuous attention of numerous observers.

Several months still remain in which material for study will be collected, and it is too early to know the results of the evidence already at hand. But it is believed that the photographic records of the comet's behavior will increase greatly our general knowledge of comets and bear especially strongly upon present theories regarding tail formation.

Extensive series of photographs have been taken by the observers at Greenwich, by M. QUÉNISSET and M. BALDET at the observatory of Juvisy, and by Professor BARNARD at Williams Bay. And no doubt the German observers and others have been photographing the comet. Extraordinary outbursts were recorded by one or more observers on or about September 16th and 30th and October 1st, 6th, and 15th. It is regretted that because of less favorable weather, none of these dates are included in the Lick Observatory series.

However, perhaps occasional astonishing transformations show no more remarkable cometary activity than the less conspicuous and more frequent developments. And it is probable that the recurrent types of activity will help most in the solution of the problem of tail formation. An early statement on this subject is made by the Astronomer Royal of England in connection with a preliminary examination of the Greenwich plates.[1] He says: "A study of the photographs shows that the form of the comet's tail exhibits a recurring series of phases, and that the phase seems to bear a relation to the condition of the nucleus which passes through cycles of stages of alternating activity and quiescence. At the stage of quiescence the comet presents the appearance of a nucleus with little enveloping coma, and straight streamers passing away at little inclination to the general direction of the tail. The coma then grows, envelopes form about the nucleus (on the side towards the Sun), and the rays of the tail become more spread. The stage of maximum activity is now reached, and larger quantities of matter appear to be expelled from the head and then driven back, forming a bright wavy tail, the streamers being no longer straight, but greatly disturbed. The bright tail then appears to be driven off and the stage of quiescence follows."

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[1] *Monthly Notices R. A. S.*, **69**, 52, 1908.

The presence of parabolic envelopes about the nucleus, such as have been seen in the large comets, is well established by the Greenwich plates. It is interesting to know that so complete is the Greenwich series of photographs that the development of these envelopes into straight rays can be watched and that the physical changes in the tail can be followed. The series of plates on which are shown the details of the coma and that portion of the tail near the head were made with the reflecting telescope of thirty inches' aperture and are, therefore, large-scale photographs. Before the above-quoted article was read, one of the Lick Observatory plates was noticed to show traces of a parabolic envelope, but so uncertain was the appearance that it was considered to be possibly only a photographic effect.

Other facts about the Lick Observatory photographs are equally interesting. Perhaps the most striking fact is the frequent occurrence of that type of tail structure which is shown in three of the illustrations. It appears as if the tail were more or less irregularly cone shaped, a skeleton conical surface being formed by long, comparatively straight shafts of luminous matter ejected from a small area of the nucleus. Having the same axis and smaller conical dimensions, there appears to be a helix of dense matter which, receding from the nucleus, expands from a tightly compressed stream into a diffuse spiral until the structure is lost in the dissipation of the material forming it. This action has been likened by Dr. CAMPBELL to the flame from a waving torch.

An interesting group of plates falls between the dates November 13 and November 18, inclusive. One image of the comet is entirely different from the next one, but of recurrent type. More resemblance exists between two plates of forty-eight hours' interval than between an intervening plate and either of these two. Long, bright streamers appear and disappear in twenty-four hours. For instance, the long streamer

5° in length in the illustration of November 16 appeared subsequent to the exposure of November 15. At any rate, there is no streamer on the earlier plate with which it can reasonably be identified. If we assume that matter has been ejected to a distance of 5° in one day, the average velocity of recession from the nucleus is greater than ninety miles per second, for ninety miles per second is roughly the velocity in the direction of the tail projected upon a plane at right angles to the line of sight. That the phenomenon is an effect of rotation is also difficult to conclude. Photographs taken at other observatories during this interval would help solve the problem.

Without doubt, the comparison of plates will show acceleration in the motion of recession from the head. One such rough measure has been made from a reproduction of a photograph[1] taken at the Observatory of Juvisy on October 16th, 7^h 45^m, Paris Mean Time, and two photographs taken at the Lick Observatory, October 16th, 10^h 20^m, and October 18th, 7^h 58^m, Pacific Standard Time. Approximate measures were made on the broadening of the tail. The distances on the three plates are 1°.5, 1°.9, and 4°.3. The resulting average velocities of recession from the head in the direction of the tail are twenty-seven miles (44^{km}) and thirty-six miles (58^{km}) per second for the first and second intervals, respectively.

Much work remains to be done, and the detailed results will be published in a subsequent *Lick Observatory Bulletin*.

LICK OBSERVATORY, January 28, 1909.

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[1] *Ccmptes Rendus*, **147**, 1035.

PLANETARY PHENOMENA FOR MAY AND JUNE, 1909.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

Full Moon.....	May 5,	4^h 8^m A.M.	Full Moon....	June 3,	5^h 25^m P.M.
Last Quarter...	" 12,	1 45 P.M.	Last Quarter...	" 10,	6 43 P.M.
New Moon....	" 19,	5 42 A.M.	New Moon....	" 17,	3 28 P.M.
First Quarter..	" 26,	5 28 P.M.	First Quarter..	" 25,	10 43 A.M.

There will be two eclipses during June.

The first is a total eclipse of the Moon on June 3d, and it will be visible in part at least over the United States, except the extreme western portion. For the extreme eastern states total eclipse begins shortly before sunset, while for the states along the Pacific Coast the eclipse will be about ended at sunset.

The second is a central eclipse of the Sun on June 17th, the line of central eclipse running from Siberia across the Arctic Ocean and south through Greenland. On the central line it is an annular eclipse at the beginning and end of its path and a total eclipse in the middle part. It will be visible as a partial eclipse in the late afternoon throughout the United States, except that part south of a line running from San Francisco southeast into the Gulf of Mexico. The local times for beginning and end at Ogden, Utah, are 4^h 48^m P.M. and 6^h 3^m P.M.

The summer solstice, the time when the Sun reaches its most northerly point, occurs June 21st, 6^h P.M., Pacific time.

Mercury passed superior conjunction with the Sun on April 1st and became an evening star, and will remain an evening star until June 14th, when it passes inferior conjunction and becomes a morning star. The month of May affords the best time of the present year for seeing the planet. On May 1st the interval between the setting of the Sun and of the planet is just about one hour, and this interval rapidly increases as the planet moves out toward greatest east elongation. It is increased by the circumstance that the planet is in the northern half of its orbit, reaching greatest heliocentric latitude on May 9th. By the middle of the month the planet does not set until nearly two hours after sunset. Greatest eastern elongation is reached on May 20th. The distance from the Sun is then 22° 23′, about an average greatest elongation. After greatest elongation the planet and Sun approach each other, but on June 1st the planet will not set until an hour and a quarter after sunset. It will therefore still be visible in the early days of June. After passing inferior conjunction on June 14th the distance between planet and Sun increases rapidly, so that by the end of the month the planet rises about an hour before sunrise.

Venus became an evening star on passing superior conjunction April 28th, and will remain an evening star until after the close of the year. On May 1st it sets only two minutes after sunset and remains too near the Sun for naked-eye visibility until after the middle of the month, and until the middle of June it sets less than an hour after sunset. It will not be a conspicuous object until autumn.

Mars rises at about $1^h\ 40^m$ A.M. on May 1st, and at about $11^h\ 30^m$ P.M. on June 28th. It moves about 36° eastward and 12° northward, from *Capricorn* through *Aquarius* into *Pisces*. Its distance from the Earth diminishes from 104,000,000 miles on May 1st, to 64,000,000 on June 30th, and its brightness nearly trebles during the two months. It is, however, at the end of June only one third as bright as it will be at opposition in late September.

Jupiter is in fine position for evening observation, being above the horizon on May 1st until about $2^h\ 30^m$ A.M. It sets earlier as the month advances, but remains above the horizon as late as $10^h\ 40^m$ P.M. on June 30th. It is stationary among the stars on May 1st, but begins to move slowly eastward, gradually increasing its rate until by the end of June it is nearly 5° east and 2° south of its position on May 1st.

Saturn became a morning star early in April. By May 1st it rises not quite an hour before sunrise, and by June 30th it rises about half an hour after midnight. It is in the constellation *Pisces* and moves about 5° east and 2° north during the two months.

Uranus rises shortly after midnight on May 1st, and shortly after 8^h P.M. on June 30th. It is in *Sagittarius*, east and north of the bowl of the "milk-dipper," and moves somewhat more than 1° westward during the period.

Neptune is in *Gemini* and is in the western sky in the evening. *Venus* passes a little less than 2° north on the evening of June 22d.

NOTES FROM PACIFIC COAST OBSERVATORIES.

ORBITS OF THE BINARY STARS 55 *TAURI*, π^2 *URSÆ MINORIS*, AND 4 *AQUARII*.

The orbit of 55 *Tauri* (= OΣ 79) was first computed by HUSSEY in 1901, but at that time there was still great uncertainty as to the form of the apparent ellipse, and the one on which his elements were based will not fit the more recent observations. The range of uncertainty is now much smaller, and it is hoped that the following elements will prove to be approximately correct. They are:—

True Elements.	Apparent Orbit.
$P = 96.3$ years	Length of major axis = $0''.92$
$T = 1898.0$	Length of minor axis = $0''.51$
$e = 0.65$	Distance of star from center = $0''.23$
$a = 0.54$	Position-angle of major axis = $48^\circ.0$
$\Omega = 77^\circ.3$	Position-angle of periastron = $205^\circ.8$
$i = \pm 55.3$	
$\omega = 114.35$	
Angles increasing.	

No orbit has heretofore been published of the binary star π^2 *Ursæ Minoris* (= Σ 1989), although the angular motion since discovery in 1832 exceeds 270°. This is mainly due to the uncertainty attaching to the early observations. The following elements give satisfactory residuals for these observations, as well as for the more reliable of my recent measures made when the angular separation of the two components was less than $0''.10$. Nevertheless the results must be regarded as subject to a large degree of uncertainty. They are:—

True Elements.	Apparent Orbit.
$P = 115$ years	Length of major axis = 0″.82
$T = 1902.7$	Length of minor axis = 0″.24
$e = 0.80$	Distance of star from center = 0″.33
$a = 0''.42$	Position-angle of major axis = 11°.45
☊ = 16°.3	Position-angle of periastron = 189°.2
$i = \pm 62.25$	
$\omega = 165.0$	

Angles decreasing.

The following orbit of 4 *Aquarii* (= Σ 2729) was computed in 1905, because of the very large residuals resulting from the comparison of my measures with SEE's elements. They were not published at that time, however, because of the uncertainty introduced by the discordance of the early measures. Since then LEWIS has published an orbit with nearly the same period as that here given, but with different geometric elements. For this reason it seems desirable to place my results on record, especially as they represent the measures of the past four years within the limit of error of measurement. They are:—

True Elements.	Apparent Orbit.
$P = 135.6$ years	Length of major axis = 1″.21
$T = 1899.8$	Length of minor axis = 0″.57
$e = 0.35$	Distance of star from center = 0″.12
$a = 0''.64$	Position-angle of major axis = 165°.4
☊ = 164°.8	Position-angle of periastron = 221°.2
$i = \pm 62.3$	
$\omega = 73.3$	

Angles increasing.

More detailed accounts of these investigations will be published later.

R. G. AITKEN.

March, 1909.

THE PERIOD OF *β CANIS MAJORIS*.

An extensive series of spectrograms of *β Canis Majoris* has been obtained. This star was announced as a spectroscopic binary a few months ago. The period of velocity variation is very close to six hours. This star, therefore, has a shorter period than any other known spectroscopic binary except *β Cephei*. The period of *β Cephei* was found by FROST to be $4^h\ 34^m.2$.

The velocity of *β Canis Majoris,* reduced to the Sun, varies between $+23^{km}$ and $+42^{km}$ per second. The interval between greatest positive and greatest negative velocity is two and a half hours. It is fortunate that the star is bright (2.6 phot. mag.). In fair seeing, and with a slit-width of 0.0013 inch, an exposure of eighteen minutes produces a well-exposed spectrogram. If an exposure of two hours had been required, the binary character of this star might easily have escaped detection.

It is not impossible that some of the fainter stars having broad and fuzzy lines are spectroscopic binaries of short period. On such stars it will be necessary to reduce the exposure time as much as possible, by using a wide slit and probably also a low dispersion.

SEBASTIAN ALBRECHT.

February, 1909.

THE VISIBILITY OF MT. WHITNEY FROM MT. HAMILTON.

In a note in No. 124 of these *Publications,* I stated my reasons for thinking that Mt. Whitney was visible from Mt. Hamilton. Professor WRIGHT has made some further investigations and computations on this matter and concludes that it is not Mt. Whitney but the Kaweah Peaks which I have observed.

The identification of Mt. Whitney in my note depends to a great extent on the computed bearing, which appears to be in error by a sufficient amount to make it coincide with the observed bearing of the Kaweah Peaks, and that Mt. Whitney is in reality just obscured by Milestone Peaks and the ridge which extends from them to the southwest.

April 2, 1909.

C. D. PERRINE.

LECTURES AT BERKELEY.

The following course of lectures was given during the present semester before the class in Modern Astronomy at the University of California:—

Dr. JOSEPH H. MOORE, Assistant Astronomer Lick Observatory—Thursday, March 18th, and Saturday, March 20th. Subject, "Periodic Variable Stars."

Dr. GEORGE E. HALE, Director Mt. Wilson Solar Observatory—Saturday, March 27th. Subject, "Solar Vortices and Magnetic Fields."

Dr. R. G. AITKEN, Astronomer Lick Observatory—Tuesday, March 30th; subject, "Comets." Thursday, April 1st; subject, "Visual and Spectroscopic Binary Stars."

R. T. CRAWFORD.

RESIGNATION OF ASTRONOMER PERRINE.

Dr. CHARLES DILLON PERRINE, of the Lick Observatory staff, has been appointed Director of the Argentine National Observatory at Cordoba, in succession to the late Dr. THOME. Dr. PERRINE left Mount Hamilton on March 29th, *en route* to Cordoba.

Dr. PERRINE's astronomical career has been a remarkable one in many particulars. Prevented by circumstances from securing an academic education, he nevertheless looked forward to engaging in astronomical work. Resigning an important commercial position in 1893, he came to the Lick Observatory in the capacity of Secretary, with the fixed purpose of devoting his spare time to the study of astronomical and related subjects, by way of preparation for later observatory duties. In 1895 his title was changed to Secretary and Assistant Astronomer. He was appointed Astronomer in the Lick Observatory in 1905. His first successes, the discovery of thirteen comets (1895 to 1900), were made as a result of systematic searches undertaken outside of his assigned duties. Dr. PERRINE was awarded the Lalande Prize of the Paris Academy of Sciences in 1897, and the gold medal of the Mexican Astronomical Society in 1905. He was elected Associate of the Royal Astronomical Society in 1904. He received the degree of Doctor of Sciences from Santa Clara College in 1905.

The writer recognizes with pleasure that Dr. PERRINE's contributions to our knowledge of comets, of satellites, of solar eclipse phenomena, of nebulæ and star clusters, of solar parallax, etc., are important factors in the history of the Lick Observatory. He regrets,—giving expression to only one of many feelings,—that he and Dr. PERRINE, who have observed three eclipses together, will probably not be able to observe a fourth eclipse in common again. It is a great satisfaction, however, to know that Dr. PERRINE's experience and skill, acquired in the Lick Observatory, will be devoted to the development of astronomy in the southern hemisphere.

The sentiments of the Observatory community concerning the departure of Mr. and Mrs. PERRINE were expressed through the presentation of a loving-cup.

W. W. CAMPBELL.

GENERAL NOTES.

Variation of Latitude.—In the *Astronomische Nachrichten* No. 4287 Dr. ALBRECHT publishes an article giving provisional results of the International Latitude Service on the southern parallel during the interval 1906.4 to 1908.4. The programme of work for the southern parallel is similar to that of the northern parallel and the chief interest in the results centers about the z-term, which represents that part of the variation which is independent of the longitude of the place of observation, and which, at one time, was thought to be due to a periodic movement of the center of gravity of the earth along the axis of rotation. The observations show this term to have practically the same value for the southern parallel as for the northern, which shows that the above-mentioned hypothesis cannot be a true one. There is a phase difference of about one tenth of a year between the two values of the z-term, but the number of observations made on the southern parallel is not sufficiently great to demonstrate the reality of this part of the phenomenon.

Dr. ALBRECHT makes the statement that the observations at Bayswater, Australia, would be discontinued at the end of January, 1909. The work at Oncativo, however, was taken over by the Argentine Republic in July, 1908, and will be continued for an indefinite length of time. S. D. T.

Notes from "Science."—Mr. R. JAMES WALLACE, who has for several years past been engaged in photographic research at the Yerkes Observatory, as instructor in photophysics, has resigned his position there to become director of the research laboratory of the Cramer Dry Plate Company, of St. Louis. It is a promising evidence of appreciation of research that a commercial company engages the services of a scientific investigator for the improvement and further development of its products.

Dr. GEORGE E. HALE, of the Solar Observatory of Mount Wilson, has been appointed a delegate to represent the National Academy of Sciences at the Darwin Celebration at Cambridge.

Solar Eclipse.—In *Monthly Notices,* November, 1908, Dr. DOWNING gives details of the total solar eclipse of 1911, April 28, at Neiafu, on Vavau Island, in the South Pacific. The meteorological conditions are only fairly promising.

Professor W. W. PAYNE has retired, under the Carnegie Foundation, from the directorship of the Goodsell Observatory of Carlton College, and is succeeded by Dr. H. C. WILSON. Professor PAYNE still retains the ownership and editorship of *Popular Astronomy.*

Professor E. BECKER, Director der Kaiserlichen Universitätes Sternwarte zu Strassburg, has been made professor emeritus and has been succeeded by Professor J. BAUSCHINGER, Director des Astronomischen Recheninstituts in Berlin.

Dr. SIDNEY D. TOWNLEY, of Leland Stanford Junior University, was recently promoted to an associate professorship in applied mathematics.

Astrophysics, Proposed Professorship at Cambridge.—The Council of the Senate report that they have had under their consideration the position of the study of astrophysics in the university, in connection with the offer of the Royal Society to give to the university the equipment of Sir WILLIAM HUGGINS's observatory.

The study of astrophysics, which is growing rapidly and resulting in large accessions to knowledge, has a special interest for the University of Cambridge, from the fact that it is so intimately associated with the work of Sir GEORGE STOKES on the meaning of the Fraunhöfer lines in the solar spectrum. In 1889 the late Mr. R. S. NEWALL gave to the university a large refracting telescope specially adapted for the study of stellar physics, and the sole charge of this telescope was entrusted to his son, Mr. H. F. NEWALL, under conditions which he generously accepted. For the last eighteen years the work of the department has been most successfully carried out by Mr. H. F. NEWALL, and important scientific results have been obtained. In 1905 the department was strengthened by the McClean bequest of £5000 for the provision of improved instrumental equipment for the Newall observatory, and now the possession by the university of the instruments used by Sir WILLIAM HUGGINS will further increase the means of observation at the disposal of the department.

In 1907 an assistant in astrophysics was appointed for five years, who is paid £100 a year by the university and £100 a year by Mr.

NEWALL. The university is fortunate in having for so long a time had the advantage of the gratuitous and most generous services of one who stands in the front rank of astrophysicists, and Mr. NEWALL'S eminence in the study is undoubtedly one of the reasons which prompted the Royal Society—at the suggestion, as the council understand, of Sir WILLIAM HUGGINS himself—to make their recent offer.

The Council of the Senate are of opinion that the time is opportune for giving further recognition in Cambridge to astrophysics. They have consulted the General Board of Studies, and with their approval desire to recommend to the Senate the establishment of a professorship of astrophysics, without stipend, and limited to the tenure of office of the first professor, in accordance with Statute B. ' The Council recommend accordingly.—*London Standard.*

Royal Astronomical Society.—The annual meeting of the Royal Astronomical Society was held at Burlington House February 12th, Mr. H. F. NEWALL, the president, occupying the chair.

The president, on behalf of the members, extended a cordial welcome to Professor O. BACKLUND, Director of the Observatory, Pulkowa, Russia, to whom the society's gold medal had been awarded for his researches concerning the comet which was first observed in 1786, and has borne the name of Encke since that astronomer in 1819 established its periodicity. Professor BACKLUND had calculated the perturbations from 1819, and had demonstrated that the motion of the comet was constant to 1858, and then, after having diminished, was again constant during the period between 1851 and 1891. He had given an interesting account of the value of the forces opposing the motion of the comet, and had applied himself to a difficult branch of research with a measure of devotion and success which made it the desire of the society to express its admiration of his scientific achievements. Amid loud cheers the president handed the gold medal to Professor BACKLUND.

The Jackson-Gwilt bronze medal and gift were handed to Mr. P. MELOTTE, of the Royal Observatory, Greenwich, in recognition of his discovery of the eighth satellite of *Jupiter.*

The president, in an address, suggested for consideration the question whether the main characteristics of the spectroscopic phenomena of the Sun and stars are dictated mainly by matter constantly streaming in upon them, and not by matter within them.

A ballot resulted in the election of Sir DAVID GILL as president of the society for the coming year.—*London Times.*

NEW PUBLICATIONS.

ABETTI, ANTONIO. Osservazioni astronomische fatte all' equatoriale di Arcetri nel 1907. Firenze. 1908. 4to. 76 pp. Paper.

Almanaque náutico para el año 1910, Calculado de orden de la Superioridad en el Instituto y Observatorio de Marina de San Fernando para el meridiano de Greenwich. San Fernando. 1908. 4to. 621 pp. Paper.

ANDRÉ, CH. Les planetes et leur origine. Paris. 1909. 8mo. 386 pp. Paper.

Annuaire Astronomique pour 1909. De l'Observatoire Royal de Belgique. Bruxelles. 1909. 16mo. 605 pp. Cloth.

Annuario del Observatorio de Madrid para 1909. Madrid. 1908. 16mo. 525 pp. Boards.

BRILL, ALFRED. Über die Elastizität der Erde. Inauguraldissertation. Göttingen. 1908. 8vo. 67 pp. Paper.

HARTWIG, ERNST. Katalog und Ephemeriden veränderlicher Sterne für 1909. Leipzig. 1909. 8vo. 90 pp. Paper.

JAEGERMANN, RICHARD. Die Bewegung der Kometenschweifmaterie auf hyperbolischen Bahnen. St. Pétersbourg. 1908. Folio. 80 pp. Paper. Price, 4 marks.

Memoirs of the Royal Astronomical Society. London. 1908. 4to. Boards.

Vol. LVII, Part III, Tables for computing standard co-ordinates on photographic plates. ARTHUR R. HINKS. 13 pp.

Vol. LVII, Part IV, Proper motions of faint stars in the Pleiades. F. J. M. STRATTON.

Double-star observations, 1902-1907. WILLIAM H. MAW. 32 pp.

Appendix II to Vol. LVII, The distribution of blue-violet light in the solar corona on August 30, 1905, as derived from photographs taken at Kalaa-es-Senam, Tunisia. 32 pp., with two plates.

Vol. LVIII, Observations of thirty-one variable stars. N. R. POGSON. 142 pp.

Vol. LIX, Part I, Theory of the motion of the Moon; containing a new calculation of the co-ordinates of the Moon in terms of the time. Part V. ERNEST W. BROWN. 103 pp.

Vol. LIX, Part II, Second index catalogue of nebulæ and clusters of stars; containing objects found in the years 1895 to 1907, with notes and corrections to the new general catalogue and to the index catalogue for 1888-1894. J. L. E. DREYER. 93 pp.

NYRÉN, M. Ascensions droites moyennes de 396 étoiles pour l'époque 1900.0. St. Pétersbourg. 1908. Folio. 12 pp. Paper.

Déclinaisons moyennes de 1375 étoiles pour l'époque 1900.0. St. Pétersbourg. 1908. Folio. 66 pp. Paper.

Observations faites au cercle méridien en 1907. Observatoire d'Abbadia. Hendaye. 1908. Folio. 349 pp. Paper.

Observatoire d'Alger. Catalogue photographique du ciel. Paris. 1908. Folio. 214 pp. Paper.

Parallaxenbestimmungen an dem Repoldschen Heliometer der Leipziger Sternwarte. B. PETER. Leipzig. 1908. 4to. 14 pp. Paper. Price, 80 pfg.

Publikationen des astrophysikalischen Observatoriums zu Potsdam. Potsdam. 1908. Folio. Paper.

Photographische Himmelskarte. Zone + 31° bis + 40° Deklination Katalog. Ergänzungen und Berichtigungen zu den Bänden I-IV. A BIEHL. 34 pp.

Nr. 46, Fünfzehnten Bändes, zweites Stück, Untersuchung über das 80^{cm} Objecto des Potsdamer Refraktors. J. HARTMANN. Mit 44 Figuren im Text und 11 Tafeln. 106 pp.

Nr. 59, Zwanzigsten Bandes, zweites Stück, Katalog von Doppelsternen der photographischen Himmelskarte aus der Zone von + 31° bis + 40° Deklination. J. SCHEINER. 43 pp.

STRUVE, HERMANN. Beobachtungen des Saturnstrabanten *Titan* am Königsberg und Berliner Refractor. Berlin. 1908. 4to. 44 pp. Paper.

Tablas para el cálculo de conjunctiones geocéntricas de las satélites de *Júpiter*. Don SALVADOR GARCIÁ FRANCAS y Don PEDRO CHARLO y JUSTO. San Fernando. 1908. 4to. 27 pp. Boards.

Transactions of the International Union for Co-operation in Solar Research. Vol. II. Manchester. 1908. 8vo. 244 pp. Cloth.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS HELD IN THE HALL OF THE CALIFORNIA CLUB, 1750 CLAY STREET, SAN FRANCISCO, MARCH 27, 1909, AT 7:30 P. M.

The following Directors were present: BURCKHALTER, TOWNLEY, MORSE, CUSHING, HALE, GALLOWAY, and CRAWFORD. President BURCKHALTER presided.

The report of the Nominating Committee was presented and accepted.

A written report was presented by the committee on location. After discussion it was moved and seconded that the President and Secretary be empowered to lease the room in the Phelan Building recommended by the committee, the rental being $20 per month. Carried.

The Secretary presented and read a letter from Dr. G. W. HILL accepting very gratefully the Bruce Medal for 1909.

The following were elected to membership:

Miss FLORENCE BROWN, 2702 Virginia Street, Berkeley, Cal.

Mr. H. C. WILLIAMS, 1476 Washington Street, San Francisco.

The following were elected institutional members:

Philadelphia Observatory—Broad and Green Streets, Philadelphia, Pennsylvania.

Smith College Library—Northampton, Massachusetts.

Washington University Library—St. Louis, Missouri.

Exchange with the *Gazette Astronomique* of the "Société d'Astronomié d'Anvers" was authorized.

The minutes of the last meeting of the Board were approved.

Adjourned.

MINUTES OF THE TWENTY-FIRST ANNUAL MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE HALL OF THE CALIFORNIA CLUB, 1750 CLAY STREET, SAN FRANCISCO, MARCH 27, 1909, AT 8 P. M.

President BURCKHALTER presided.

The minutes of the last meeting of the Society were approved.

The report of the nominating committee was presented and printed ballots distributed, after which the polls were opened. The polls were closed at 9 P. M. and Messrs. MCADIE and BAIRD were appointed tellers to canvass the returns.

The report of the auditing committee was presented by Chairman ZIEL.

Moved and seconded that the report be received and all criticising matter be stricken out.

A motion to table the report temporarily was made, seconded and carried. After the address of the evening the previous question was put and carried.

Mr. ZIEL presented a further report concerning a certain adjustment in the funds. No action.

The annual report of the Treasurer was presented by Director GALLOWAY in the absence of Treasurer RICHARDSON. The report was accepted.

The following resolution was introduced:

Resolved, That all the acts appearing in the minutes of the meetings of the Board of Directors of this Society, as having been done by the said Board during the past fiscal year, are here now, by this Society, approved and confirmed. Moved, seconded and carried.

The Secretary presented and read the letter of Dr. G. W. HILL accepting the Bruce Medal.

President BURCKHALTER formally presented the Bruce Medal for 1909 to Dr. G. W. HILL. As Dr. HILL could not be present to receive the medal, the President directed the Secretary to send it to him with expressions of good wishes and the high esteem in which the Society holds him.

President BURCKHALTER then introduced Dr. GEORGE ELLORY HALE, Director of the Mount Wilson Solar Observatory, who delivered a most interesting address upon "The Work of the Mount Wilson Solar Observatory." The lecture was profusely illustrated with stereopticon views.

Upon the conclusion of the address it was moved and seconded that a vote of thanks be given to Dr. HALE. The motion was carried by a rising vote.

The tellers reported that the following had received a majority of the votes cast for Directors: C. BURCKHALTER, W. W. CAMPBELL, G. E. HALE, F. MORSE, R. G. AITKEN, D. S. RICHARDSON, W. H. CROCKER. C. S. CUSHING, J. D. GALLOWAY, R. T. CRAWFORD, E. J. MOLERA. These eleven were then declared elected to be Directors for the ensuing year.

The tellers reported that the following had received a majority of the votes cast for Committee on Publication: S. D. TOWNLEY, J. D. MADDRILL, H. D. CURTIS. These three were then declared elected to be members of the Committee on Publication for the ensuing year.

Adjourned.

REPORT OF THE DONOHOE COMET-MEDAL COMMITTEE FOR THE YEAR 1908.

The following comets were discovered during the year 1908:—

Comet *a* 1908, an unexpected comet, was discovered (photographically) by Professor Dr. MAX WOLF, at Heidelberg, on January 2, 1908.

Comet *b* 1908, ENCKE's comet, was observed on its return by Mr. R. WOODGATE, at the Cape of Good Hope, on May 27, 1908.

Comet *c* 1908, an unexpected comet, was discovered (photographically) by Professor D. W. MOREHOUSE, at the Yerkes Observatory, on September 1, 1908.

The Donohoe Comet-Medal of the Astronomical Society of the Pacific has been awarded to the discoverers of comets *a* and *c*.

The number of Donohoe Comet-Medals awarded to date is sixty-six.

Respectfully submitted.

March 27, 1909.

W. W. CAMPBELL,
C. D. PERRINE, } *Committee.*
S. D. TOWNLEY,

TREASURER'S REPORT.

GENERAL STATEMENT OF THE FUNDS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC ON MARCH 27TH, 1909.

In the William Alvord Fund	$ 5,008 56
Alexander Montgomery Library Fund	3,818 51
Donohoe Comet-Medal Fund	727 68
Bruce Medal Fund	2,652 94
Life Membership Fund	1,924 36
John Dolbeer Fund	5,000 00
General Fund	853 56
Total	$19,985 61

ASSETS.

Bonds on deposit in the Mercantile Trust Co	$14,418 02
Cash on deposit Humboldt Savings Bank	331 94
" " " Savings and Loan Society	437 06
" " " Security Savings Bank	659 49
" " " San Francisco Savings Union	727 68
" " " Mutual Savings Bank	663 22
" " " German Savings and Loan Society	924 36
" " " Union Trust Company	970 28
" " " Donohoe-Kelly Banking Company	853 56
Total	$19,985 61

TRANSACTIONS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC FOR THE FISCAL YEAR ENDING MARCH 27, 1909.

WILLIAM ALVORD FUND.

DR.	
Balance March 28, 1908—	
Bonds with Mercantile Trust Company	$ 4,239 56
Cash in Humboldt Savings Bank	331 94
Cash in Savings and Loan Society	437 06
Interest received on Bonds during year	200 00
On Humboldt Bank Deposit	13 53
On Savings and Loan Deposit	8 74
	$ 5,230 83

Cr.

Interest on Bonds transferred to General Fund	$200 00	
On Humboldt Bank Deposit, General Fund	13 53	
On Savings and Loan Deposit, General Fund	8 74	
		$ 222 27
Balance March 27, 1909		$ 5,008 56

BRUCE MEDAL FUND.

Dr.

Balance March 28, 1908—		
Bonds in Mercantile Trust Company		$ 1,989 72
Cash in Mutual Savings Bank		832 21
Interest received on Bonds during year		100 00
On Mutual Savings Bank Deposit		32 03
Refund by French Mint		64
		$ 2,954 60

Cr.

By one gold medal from French Mint	$100 00	
Expressage and postage	5 00	
Transfer to Life Membership Fund	196 66	
		301 66
Balance March 27, 1909		$ 2,652 94

DONOHOE COMET MEDAL FUND.

Dr.

Balance Cash March 28, 1908, in San Francisco Savings Union	$ 698 35
Interest on Deposit for year	29 33
Balance March 27, 1909	$ 727 68

ALEXANDER MONTGOMERY LIBRARY FUND.

Dr.

Balance March 28, 1908—	
Bonds in Mercantile Trust Company	$ 3,159 02
Cash Security Savings Bank	549 42
Interest on bonds	150 00
Interest on deposit in Security Savings Bank	20 07
	$ 3,878 51

Cr.

By allowance on account salary of Secretary	60 00
Balance March 27, 1909	$ 3,818 51

LIFE MEMBERSHIP FUND.

Dr.

Balance March 28, 1908—		
Bonds in Mercantile Trust Company		$ 1,000 00
Cash in German Savings and Loan		727 70
Interest on bonds		40 00
Interest on deposit in German Savings and Loan		29 55
Transfer from Bruce Medal Fund		196 66
		$ 1,993 91

Cr.

By Interest on bonds to General Fund	$ 40 00	
Interest on bank deposit to General Fund	29 55	
		69 55
Balance March 27, 1909		$ 1,924 36

JOHN DOLBEER FUND.

Dr.		
Balance March 28, 1908—		
Bonds in Mercantile Trust Company		$ 4,029 72
Cash in Union Trust Company		970 28
Interest on bonds		190 00
Interest on bank deposit		35 22
Cr.		$ 5,225 22
Interest on bonds to General Fund	$190 00	
Interest on bank deposit to General Fund	35 22	
		225 22
Balance March 27, 1909		$ 5,000 00

GENERAL FUND.

Dr.		
To Receipts as follows:		
Balance March 28, 1908		$ 619 10
From sale of *Publications*		72 34
Dues		858 27
Exchange of Edison Electric Bonds		192 23
Rhine and Moselle Company—Insurance		125 00
Cushing & Cushing—fees returned		12 50
Duplicate check returned		2 00
Alexander Montgomery Library Fund		60 00
William Alvord Fund—interests		222 27
John Dolbeer Fund—interests		225 22
Life Membership Fund—interests		69 55
Total		$ 2,458 48
Cr.		
By Expenditures as follows:		
C. A. Murdock and Company, Printing—including Publications 118 to 124, inclusive	$1,146 70	
Salary of Secretary	160 00	
Salary of Treasurer	60 00	
Printing, postage, expressage, etc., by Secretary	67 92	
Postages by other officials	14 95	
Carnegie Institute Hand Book	4 00	
Astronomical Journal	5 00	
University of Chicago	30 00	
Hall rent, meetings of March, 1908 and 1909	40 25	
Lantern service, March 28, 1908	12 00	
Miscellaneous printing	17 05	
Safe-deposit box	4 00	
Making seal for the Society	10 00	
Mercantile Trust Company, care of bonds	14 00	
Insurance of library	4 75	
Miscellaneous	14 30	
		1,604 92
Balance March 27, 1909		$ 853 56

Dues unpaid for 1909	$510 00
Dues unpaid for 1908	135 00
Dues unpaid for 1907	90 00
	$735 00

No unpaid bills on hand.

Funds of the Astronomical Society of the Pacific Held in Deposit by the Mercantile Trust Company of San Francisco, at 464 California Street.

These securities are all of the face denomination of $1,000, and the values given represent their original cost to the Society.

Life Membership Fund.	
One South Pacific Coast Railroad Company's 1st mortgage, guaranteed 4 per cent Gold Bond, No. 3406. Principal due July, 1937, interest payable in January and July	$ 1,000 00
Alexander Montgomery Library Fund.	
One Oakland Transit consolidated 1st consolidated mortgage 5 per cent Gold Bond, No. 4328. Principal due July, 1932, interest payable in January and July	1,040 00
One Sunset Telephone and Telegraph Company's consolidated mortgage 5 per cent Gold Bond, No. 641. Principal due October, 1929, interest April and October	1,084 02
One Contra Costa Water Company's 5 per cent Gold Bond, No. 1665. Principal due January, 1915, interest payable January and July	1,035 00
Bruce Medal Fund.	
One Bay Company's Power Company 1st consolidated mortgage 5 per cent Sinking Fund Gold Bond No. 1636. Principal due September, 1930, interest payable in March and September	1,012 50
One Edison Electric Company, Los Angeles, 1st and refunding mortgage 5 per cent Gold Bond, No. 6836. Principal due September, 1922, interest payable in March and September	977 22
John Dolbeer Fund.	
One South Pacific Coast Railway Company's 1st mortgage 4 per cent guaranteed Gold Bond, No. 3407. Principal due July, 1937, interest payable in January and July	1,000 00
One Oakland Transit Consolidated 1st consolidated mortgage 5 per cent Gold Bond, No. 4329. Principal due July, 1932, interest payable January and July	1,040 00
One Bay Counties Power Company's 1st consolidated mortgage 5 per cent Sinking Fund Gold Bond, No. 1637. Principal due September, 1930, interest payable in March and September	1,012 50
One Edison Electric Company, Los Angeles, 1st and refunding mortgage 5 per cent Gold Bond, No. 6837. Principal due September, 1922, interest payable March and September	977 22
William Alvord Fund.	
Two Sunset Telephone and Telegraph Company's consolidated mortgage 5 per cent Gold Bonds, Nos. 656 and 657. Principal due October, 1929, interest payable in April and October	2,168 06
Two Contra Costa Water Company's 5 per cent Gold Bonds, Nos. 87 and 1666. Principal due January, 1915, interest payable in January and July	2,071 50
Total, 14 bonds; value	$14,418 02

D. S. Richardson, *Treasurer.*

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD IN THE HALL OF THE CALIFORNIA CLUB, 1750 CLAY STREET, SAN FRANCISCO, MARCH 27, 1909, AT 10:15 P. M.

Present: Directors BURCKHALTER, HALE, MORSE, GALLOWAY, CUSHING, MOLERA, CRAWFORD.

Retiring President BURCKHALTER called the meeting to order.

Director W. W. CAMPBELL was elected to be President.

Director GEO. E. HALE was elected to be First Vice-President.

President CAMPBELL being absent, Vice-President HALE then took the chair. The election to the remaining offices resulted as follows:

Second Vice-President: F. MORSE.

Third Vice-President: E. J. MOLERA.

Secretary and Treasurer: D. S. RICHARDSON.

Secretary (Lick Observatory): R. G. AITKEN.

Comet Committee: CAMPBELL (ex-officio), TOWNLEY, CURTIS.

Library Committee: CRAWFORD (Chairman), TOWNLEY, EINARSSON.

Moved, seconded and carried, that the matter of arranging the transfer of the Society's property to the new room in the Phelan Building, and the furnishing of the room be left to the Chairmen of the Committees on Finance and Library.

Moved and seconded that the Library Fund be charged ten dollars per month for the rent of the new room, and that an amount equal to the insurance received from the Rhine and Moselle Insurance Co. now in the General Fund be applied to fitting up the room. Carried.

Moved and seconded that the salary of the Secretary-Treasurer be twenty dollars per month, of which five dollars is to be taken from the Library Fund.

The Committee on Publication recommended the adoption of the following resolutions:

Resolved, That hereafter the day of the month be omitted from the date of the *Publications*.

Carried provided that the change is not contrary to the postal regulations in regard to second-class matter.

Resolved, That the Chairman of the Committee on Publication be authorized to employ whatever clerical help may be necessary in getting out the *Publications*, the total expenditures for this purpose in any one year not to exceed the sum of forty dollars.

Carried.

Resolved, That the interest from the Life Membership Fund, the John Dolbeer Fund and the Wm. Alvord Fund for the year 1909 be turned into the General Fund to be applied toward the cost of printing the *Publications*.

Carried.

Resolved, That no award of the Bruce Medal be made for the year 1910.

Carried.

The Committee on Publication of the Astronomical Society of the Pacific, to which the matter of amendments to the By-Laws was referred, reported as follows:

1. The By-Laws of the Society, the statutes for the bestowal of the Bruce Medal and the rules relating to the comet medal, were last printed in 1897, as Number 57 of the Publications, volume 9, page 163.

2. Since 1897 the By-Laws have been amended three times, as follows: (a) Article VIII, January 31, 1903 (see vol. 15, p. 52); (b) article IX, March 28, 1903 (see vol. 15, p. 141); (c) article II, August 31, 1905 (see vol. 17, p. 169).

3. We recommend that the second paragraph of article IX of the By-Laws be amended to read as follows:

> A meeting shall be held in the Library of the Lick Observatory at a suitable hour on the last Saturday of August; and meetings shall be held in the rooms of the Society, in San Francisco, at eight o'clock p. m. on the last Saturdays of January, March, June and November, but it shall be within the discretion of the President to designate other places of meeting, in San Francisco or vicinity, for the meetings of January, June and November, whenever, in his opinion, such change will be to the advantage of the Society.

4. We recommend that when the statutes for the bestowal of the Bruce Medal are reprinted, a foot note be added to the tenth line of Article V, to read as follows: In response to a request made by one of the nominating observatories, the Board of Directors of the Astronomical Society of the Pacific construes the provision in Article V of the Statutes, referring to "Astronomers worthy to receive the medal for the ensuing year," to cover services rendered during the lifetime of the nominee.

It was the unanimous opinion of the six Directors present that the By-Laws be amended as recommended by the Committee, and the Secretary was instructed to obtain, if possible, the written consent of at least three other Directors.

The printing of the footnote to article V of the Bruce Statutes was authorized.

Adjourned.

ADDENDUM TO MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN ROOM 601, MERCHANTS' EXCHANGE BUILDING, SAN FRANCISCO, NOVEMBER 28, 1908, AT 2 O'CLOCK P. M.

Now that the announcement of the eighth award of the Bruce Gold Medal has been made, this addendum to the minutes of the meeting of the Board of Directors held November 28, 1908, is published and made part of the complete minutes of said meeting.

The result of the ballot showed that ten votes were cast for Dr. G. W. HILL. As the Statutes for the Bestowal of the Bruce Medal require at least six votes, and more than this number having been cast for Dr. G. W. HILL, the award was thereupon made to him. The following certification was signed by the Directors:—

This is to certify that a special meeting of the Board of Directors of the Astronomical Society of the Pacific was held this day for the purpose of awarding the Bruce Medal for the year 1909, and that, the provisions of the statutes for the bestowal having been complied with, the medal was awarded to

GEORGE WILLIAM HILL

for distinguished services to astronomy, by the consenting votes of ten Directors.

CHARLES BURCKHALTER, S. D. TOWNLEY, FREMONT MORSE, CHARLES S. CUSHING, D. S. RICHARDSON, R. T. CRAWFORD, J. D. GALLOWAY, GEO. E. HALE,* R. G. AITKEN,* W. W. CAMPBELL.*

SAN FRANCISCO, CAL., November 28, 1908.

---

* By proxy.

OFFICERS OF THE SOCIETY.

Mr. W. W. Campbell	*President*
Mr. G. E. Hale	*First Vice-President*
Mr. F. Morse	*Second Vice-President*
Mr. E. J. Molera	*Third Vice-President*
Mr. D. S. Richardson	*Secretary and Treasurer*
Mr. R. G. Aitken (Mount Hamilton, Cal.)	*Secretary*

Board of Directors—Messrs. Aitken, Burckhalter, Campbell, Crawford, Crocker, Cushing, Galloway, Hale, Molera, Richardson.

Finance Committee—Messrs. Molera, Crocker, Cushing.

Committee on Publication—Messrs. Townley, Maddrill, Curtis.

Library Committee—Messrs. Crawford, Townley, Einarsson.

Comet-Medal Committee—Messrs. Campbell (ex-officio), Townley, Curtis.

NOTICE.

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January of each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary at Berkeley ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, S. D. Townley, Stanford University, California.

The Secretary at Berkeley will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage.

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, and November, and at the Lick Observatory on the last Saturdays of June and August. Members who propose to attend the meetings at Mount Hamilton should communicate with the Secretary at Berkeley, in order that arrangements may be made for transportation.

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Harvard University
JUL 5 1909

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COMMITTEE ON PUBLICATION.

Sidney D. Townley, Stanford University, Cal.
James D. Maddrill, Ukiah, Cal.
Heber D. Curtis, Mount Hamilton, Cal.

PUBLICATIONS

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THE CLOSING OF A FAMOUS ASTRONOMICAL PROBLEM.[1]

BY W. W. CAMPBELL.

There is perhaps no more striking illustration of the power of scientific method than that relating to the discovery of *Neptune* in 1846. The planet *Uranus,* until then the outermost known member of our solar system, refused to follow the path computed for it by mathematical astronomers. With the progress of time the discrepancies between its predicted and observed positions grew constantly larger until, in the early eighteen-forties, the discordance amounted to fully seventy-five seconds of arc. This is a small angle—not more than one twenty-fifth the angular diameter of our moon—yet a very large angle to refined astronomy, for a discrepancy of two seconds would have been detected with ease. The opinion gradually developed that *Uranus* was drawn from its natural course by the attractions of an undiscovered planet still farther from the Sun than itself. ADAMS in 1843 and LE VERRIER in 1845, independently, and each without knowledge of the other's plans, attacked the then extremely difficult problem of determining the approximate orbit, mass, and position of an undiscovered body whose attractions should produce the perturbations observed. Regrettable and avoidable delays occurred in searching for the planet after ADAMS's results were communicated to the astronomer royal, in October, 1845. LE VERRIER's results were communicated to the Berlin Observatory in September, 1846, with the request that a search be made. The disturbing planet, later named *Neptune,* was found on the first evening that it was looked for, less than one degree of arc from the position assigned by LE VERRIER. If an energetic search had been made in England the year before, the planet would have been discovered within two degrees of the position assigned by ADAMS.

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[1] Reprinted, by special permission, from *The Popular Science Monthly,* May, 1909.

The above résumé of this unsurpassed achievement of the human mind forms a natural prelude to the present article, as it was the immediate forerunner of another problem, famous for half a century, which has now been brought to a satisfactory conclusion.

The determination of the orbit of the planet *Mercury* gave great difficulty to its investigators, principally from two causes:—

1. Being the innermost known planet in our system, remaining always near the Sun, and usually lost to view in the Sun's glare, fairly accurate observations of its positions could be secured only when the planet was near its greatest angular distances from the Sun and on the rare occasions when the planet passed between us and the Sun's disk. Consequently, observations of the highest accuracy were few in number; and,

2. There were large discrepancies between *Mercury's* predicted and observed positions, certainly not due to the attractions of any known members of our solar system.

LE VERRIER, of Neptunian fame, undertook a systematic investigation of *Mercury's* orbit, making use of all available observations. His results were derived and published in 1859. His work established that there were peculiarities in the planet's orbital motion which could not be due to the attractions of known masses of matter. Chief among the peculiarities was a slow rotation of the orbit itself. It is best described as a forward motion of the orbit's perihelion amounting to thirty-eight seconds of arc per century.

LE VERRIER announced that the outstanding differences between prediction and observation could be produced and explained by the disturbing attractions of an undiscovered planet closer to the Sun than *Mercury* and revolving around the Sun in an orbit lying nearly in the plane of *Mercury's* orbit. The mass of (the quantity of matter in) the hypothetical planet would depend upon its distance from *Mercury:* if half way between *Mercury* and the Sun, its mass would be two thirds that of *Mercury;* if further from *Mercury,* the necessary mass would be greater; if nearer, smaller. A group or "ring" of small planets, instead of one large planet, would serve equally well, provided the total mass of the planetoids were of the same order of magnitude. LE VERRIER did not say that such an undiscovered planet or ring of planetoids did exist, but simply that it would account for the observed anomalies. The accuracy of his computations, published in detail, could not be questioned. The recognition of his masterly skill, and the memory of his entirely similar discovery of *Neptune,* assisted in convincing astronomers quite generally that a planet or group of planets existed. The discovery of the disturbing mass became at once a noted problem.

A body traveling around the Sun in a circular orbit whose radius is only one half *Mercury's* average solar distance would never be more than 12° from the Sun as viewed by terrestrial observers. A search for it by ordinary methods would accordingly be fruitless. A body large enough to shine brilliantly on a dark-sky background would be hopelessly lost in the bright sky near the Sun. *Mercury* itself, though running out between 20° and 30° from the Sun every few weeks, is seldom seen by any save astronomers; and they know where to look for it in the twilight sky.

Two special methods of discovery were applicable: (1) To detect the planet projected upon the Sun's disk when its orbital motion carried it between us and the Sun; (2) to search for it when the sky background was darkened at the time of a total solar eclipse.

Needless to say, a crop of discoverers by the first method grew up without delay. The observer of greatest note was LESCARBAULT, a rural physician of France. Immediately following the publication of LE VERRIER's conclusions, LESCARBAULT announced that he had observed the transit of an unknown planet across the Sun's disk several months earlier. LE VERRIER journeyed to LESCARBAULT's home, investigated all the circumstances of the observation, weighed the evidence, and concluded that a real planet had been seen. In fact, so convinced of its reality were many scientific men that the name *Vulcan* was given to it. Older and later reported observations of the same character, to the number of twenty, were collected by LE VERRIER, and those which seemed to be in harmony with each other were made the basis of an orbit. *Vulcan* was found to be about one third *Mercury's* distance from the Sun, revolving once around the Sun in between nineteen and twenty days. In some of the text-books on astronomy appearing in the sixties and seventies, *Vulcan* was assigned a place in the solar system as conspicuous and as secure as that of *Mercury* itself.

Now it is probable that every one of the twenty observations referred to was erroneous, though made in good faith. In essentially every case the observer was inexperienced, and used a telescope of insufficient power, or one unprovided with measuring apparatus suitable for determining whether or not the subject observed was in motion across the Sun's disk. Even the observation of LESCARBAULT was in doubt when it later transpired that a Brazilian observer of considerable professional experience was at the same hour studying the region of the Sun in question and saw only uniform normal solar surface. The situation was not without its humorous side. For example, a Mississippi Valley weather prophet who saw *Vulcan* crossing the Sun's disk, said it was about "as large as a new [*sic*] silver half dollar"! Many of the observations no doubt referred to small sunspots which, with small telescopes, would look round.

Vulcan was searched for by visual observers at the principal eclipses of the sixties, seventies, and eighties. Two noted astronomers at the eclipse of 1878, WATSON and SWIFT, believed that they saw two new planets near the Sun. However, the two seen by WATSON did not agree with those seen by SWIFT, and still other astronomers at the same eclipse saw no strange bodies in the same regions. As the assigned locations depended upon the hasty readings of graduated circles, in which one can so easily make errors, in the press and excitement of eclipse conditions, the astronomical world quickly, and no doubt correctly, concluded that the objects seen were well-known neighboring stars.

The perfecting of dry-plate photography gave renewed interest to the search for *Vulcan,* both when passing over the solar surface and at times of eclipse. Although the Sun has been photographed almost daily during the past twenty years, at one observatory or another, no experienced observer has seriously claimed that his plates recorded an unknown planet crossing the Sun. Neither were eclipse searches more successful: the well-known bright stars lying nearly in the direction of the Sun were photographed, but no strange bodies. Curiously enough, the optical principles governing the efficiency of cameras in this search were overlooked for many years, and faint objects near the Sun—say stars fainter than the fourth magnitude—were not observable, because their images, though formed on the photographic plates, were overwhelmed and buried from sight in the general darkening of the photograph by the bright-sky background. It was not until 1900 that the elements of the problem of photographing faint bodies near the Sun were comprehended. While preparing for the eclipse of that year, three astronomers, Professor W. H. PICKERING, of Harvard College Observatory, and Messrs. PERRINE and CAMPBELL, of the Lick Observatory, independently arrived at the same simple conclusion that the focal lengths of the intramercurial-search cameras should be relatively long, in order to reduce the intensity of the sky exposure on the plates without reducing the intensity of the star images, and thus let the latter be seen on the negative. The principles involved are so simple as hardly to call for elucidation.

Let the two cameras have lenses of equal aperture, say three inches, of equal transparency, and capable of covering equal *angular* fields of view, say a circle ten degrees in diameter. Let one be of short focus, twenty-one inches, and the other of long focus, 135 inches. The powers of the two lenses to record stellar points on the sensitive plates in focus, under good atmospheric conditions, are not very unequal, for the two lenses collect equal quantities of light and condense the light into images of very nearly the same size. Both collect the same quantity of sky light, but the longer-focus camera spreads it (more thinly) over an area $(135)^2/(21)^2 = 41$

times the greater. It is evident that faint-star images hopelessly lost to view on the sky-blackened small plate may be seen with ease on the nearly clear glass of the large plate. We may safely say that the large plate will show images of stars three or three and one half magnitudes fainter than the small plate. The same advantage exists for small intramercurial planets as for stars, provided the exposures do not exceed two or three minutes in length, as they seldom do at eclipses. In longer exposures on intramercurial planetoids the advantage would usually be lost, as their rapid (and unknown) motions would cause their images on the plate to move, slowly with short-focus and rapidly with long-focus cameras, thus drawing them out into trails. With the longer instrument here described, an eight-minute exposure would in general be no more effective than one of four minutes. The most successful instrument for the search in question must compromise between the advantage of long focus in reducing sky density, and the disadvantage of long focus in producing long trails. Shorter exposures, giving shorter trails, may be provided by increasing the diameter of the lens, but this in turn means greater unavoidable optical aberrations in the outer areas of the region photographed, which is a reduction in efficiency. In this as in all instruments, extensive experience and good judgment must combine to decide upon the best compromise-proportions.

Professor PICKERING, of Harvard, and Mr. ABBOT, of the Smithsonian Institution, used such cameras at the total solar eclipse of 1900. The latter observer was favored with good conditions, in North Carolina, and he secured one photograph of a considerable area surrounding the eclipsed Sun. Quite a number of the stars known to exist in this region were photographed; but in the absence of a duplicate photograph of the same region, he could not decide whether certain apparent images on the plate were due to unknown planets, or were defects such as always exist in photographic films.

At the eclipse of 1901, in Sumatra, Mr. ABBOT, of the Smithsonian Expedition, and Mr. PERRINE, in charge of the Crocker Expedition from the Lick Observatory, were prepared, with four cameras each, to secure duplicate photographs covering a large area extending east and west from the Sun. Conditions were unfortunately against the success of Mr. ABBOT's plans, but thin clouds at the time of the eclipse let twenty-five per cent of the light come through to Mr. PERRINE's photographic plates. The area covered in duplicate was 6° x 38°, extending along the direction of the Sun's equator, with the Sun in the center of the region. The plates recorded 170 well-known stars; and all apparent images not of ordinary stars were proved by the duplicate plates to be defects in the films. In two thirds of the area stars down to the eighth magnitude and many fainter ones were recorded; and in one third the area, covered with thicker clouds, stars were recorded down to the fifth and sixth magnitudes.

At the eclipse of 1905 Mr. CROCKER made it possible for me to organize expeditions to Labrador, Spain, and Egypt, each equipped with four intramercurial cameras, in addition to apparatus for other lines of research. The details of the twelve cameras were planned by Dr. PERRINE, the instruments were constructed under his supervision, and any photographic plates obtained with them at the three stations were to be assigned to him to examine for possible intramercurial-planet images. The Labrador group of four cameras, mounted at the station by Dr. CURTIS, made no contribution because of the severe storm conditions prevailing at the time of totality. The Egyptian cameras, mounted by Professor HUSSEY, recorded a considerable number of stars, but the sky, though clear in the usual sense, was full of dust, and the Sun and the surrounding region covered by the search were at a low altitude. The Spanish cameras, photographing through clouds which permitted only twenty or thirty per cent of the light to pass, recorded fifty-five stars down to about the seventh and eighth magnitudes. All suspected images not occupying the positions of known stars were proved to be defects in the films.

The eclipse of 1908 in the South Seas was utilized by the Crocker Expedition to cover a region extending east and west along the Sun's equator with duplicate exposures. Notwithstanding interference from rain and clouds at the beginning of totality, clear sky prevailed during the last two thirds of the four critical minutes. Dr. PERRINE finds more than 500 images of well-known stars on the plates, and no images of unknown bodies. Stars are recorded down to nearly the ninth visual magnitude.

It is not absolutely certain that intramercurial planets, revolving around the Sun in elliptical orbits would be seen in projection entirely within the area of 9° x 29° lying along the solar equator and equally east and west of the Sun's center, yet there are exceedingly strong reasons to believe such would be the case. The eight large planets and the 650 ± minor planets in our system revolve around the Sun in the same direction, and, excepting a small proportion of the asteroids, so nearly in the Sun's equatorial plane that the parts of their orbit planes lying within the limits for intramercurial planets would be projected upon the photographed area. The central plane of the zodiacal light differs little from the Sun's equatorial plane. It is certain, also, that any intramercurial planets originally moving in planes inclined at large angles to *Mercury's* orbit plane would gradually be compelled by the attractions of *Mercury* and the other major planets to move in planes inclined at small angles to the ecliptic. The coincidence of the satellite planes in the systems of *Jupiter* and *Saturn,* and no doubt of *Uranus* and *Neptune* also, with the equatorial planes of these planets is another analogy of some weight. Admitting, for completeness, the hypothesis of an extensive system of small planets moving in planes making a variety of angles with the ecliptic and Sun's equator, some would certainly have been caught in the region photographed. A single planet, or a half dozen planets, massive enough to meet the requirements, moving in *any* orbit planes would no doubt have been discovered a generation ago. In view of these facts, there is little reason to fear that any planets effective in disturbing *Mercury's* motions were north or south of the regions covered by photography.

Inasmuch as planets, shining by reflected light, do not act upon photographic plates so strongly as stars of the same visual magnitude, we may say that exposures which recorded stars down to the ninth magnitude should have recorded planets down to the eighth. From the known brightness, distance from the Sun, and approximate diameter of a few of the asteroids revolving in space between *Mars's* and *Jupiter's* orbits, Dr. PERRINE has computed that an average eighth-magnitude intramercurial planet could scarcely be larger than thirty miles in diameter and that roughly a million such bodies, of great density, would be required to supply the disturbing effect observed in *Mercury's* orbit.

Taking all these points into consideration, I think we may say that the investigations by PERRINE, forming a part of the work of the Crocker Eclipse Expeditions from Lick Observatory, have brought the observational side of the Intramercurial Problem, famous for a half century, definitely to a close. It is not contended that no such planets will be discovered in the future; in fact, it would not be surprising, nor in opposition to the opinions here expressed, if several such bodies should be found; but it is confidently believed that any such bodies would fail hopelessly to supply the great mass of material demanded by LE VERRIER'S theory, as PERRINE pointed out in discussing the Sumatra observations of 1901.

On the occasion of a future eclipse of fairly long duration, occurring in the dry season, it might be well to repeat the observations, inasmuch as the instruments are in approximate readiness, and the observations at the three past eclipses were made through thin clouds twice, and with cloud-shortened exposures the third time. The cameras are capable of recording tenth-magnitude stars with three-minute exposures in clear sky. It will not be advisable to use these instruments at the eclipses of the next four years.

There are other chapters, on the theoretical side of the problem, to be entered here.

Professor NEWCOMB'S researches on planetary motions extended much further than LE VERRIER'S. He found small terms in the motions of *all* the inner planets—*Mercury, Venus,* Earth, *Mars*—which are not due to the disturbing attractions of any known masses of matter. The chief discrepancies, aside from the large one found in *Mercury's* motion by LE VERRIER and confirmed by NEWCOMB,[1] are in the perihelion of *Mars*, and in the nodes of *Mercury* and *Venus*. These outstanding residuals will be tabulated on a later page.

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[1] LE VERRIER'S discrepancy amounted to 38″, NEWCOMB'S to 41″.

The attractions of any one planet or ring of small planets, sufficient to account for the excess motion of *Mercury's* perihelion, failed to account for the other discrepancies discovered by NEWCOMB for the four planets. Satisfactory causes were looked for in a possible ellipsoidal form of the Sun, in a hypothetical ring of small planets between *Mercury* and *Venus,* in an assumed minute variation in the law of gravitation from the Newtonian inverse square of distances, and in other assumptions, but in vain. One hypothesis, that the finely divided material which gives rise to the zodiacal light (by reflecting the Sun's rays) is the responsible disturbing mass, has been discussed several times since the days of LE VERRIER and as many times rejected, with one exception.

The exception is Professor SEELIGER's recently published investigation. With great skill and with entirely reasonable assumptions as to the form of space occupied by the zodiacal material, and as to the density of the distribution of the material in this space, he establishes that there is sufficient mass to account for the discrepancies in the motions of all the four planets.

The following table exhibits the results of SEELIGER's theory in the first column of figures, and the actual results of observation as determined by NEWCOMB in the second column. The quantities in the third column, which bear the sign ±, are the "probable errors" assigned by NEWCOMB to his results; and, for the benefit of non-mathematical readers, we may explain that these "probable errors," deduced from the observations themselves, are indications of the uncertainties existing in the quantities to which they are attached. In this table e and i are respectively the eccentricity of the orbit and the inclination of the orbit plane to the ecliptic; and $\Delta\Pi$, $\Delta\Omega$, and Δi are respecttively the changes, per century, in the longitude of perihelion, in the longitude of node, and in the inclination of the orbit plane, unaccounted for by the attractions of known masses, as in the second column, and produced by the attractions of the zodiacal matter as computed by SEELIGER. In the last column are the differences between the SEELIGER and NEWCOMB numbers: in other words, a comparison of theory with actuality. These differences are small. All are within the probable errors in the third column; with one exception, far within these probable errors.

		Seeliger.	Newcomb.		N.-S.
$e \cdot \Delta\Pi$	*Mercury*	+8″.49	+8″.48	±0″.43	—0″.01
	Venus	+0 .05	—0 .05	±0 .25	—0 .10
	Earth	+0 .07	+0 .10	±0 .13	+0 .03
	Mars	+0 .59	+0 .75	±0 .35	+0 .16
$\sin i \cdot \Delta\Omega$	*Mercury*	+0 .65	+0 .61	±0 .52	—0 .04
	Venus	+0 .58	+0 .60	±0 .17	+0 .02
	Mars	+0 .23	+0 .03	±0 .22	—0 .20
Δi	*Mercury*	+0 .52	+0 .38	±0 .80	—0 .14
	Venus	+0 .17	+0 .38	±0 .33	+0 .21
	Mars	—0 .02	—0 .01	±0 .20	+0 .01

We cannot ascribe this remarkable agreement between Newcomb's and Seeliger's results to fortunate chance, and it is scarcely possible to doubt that in the zodiacal-light materials lie the causes of the discrepancies referred to. I have little hesitation in venturing the opinion that Seeliger's investigation marks an epoch in the application of Newton's law of gravitation to the motions within the solar system. At one stroke he appears to have removed a group of discrepancies which served as bases for many inquiries as to the preciseness and sufficiency of the Great Law. With all respect to Seeliger's genius and labor, however, scientific caution will value confirmation of his results by other investigators.

Seeliger's assumptions as to the distribution and mass of the zodiacal material are of interest, especially when we recall that the zodiacal light within some twenty degrees of the Sun is unobservable, on account of the glare, and that the brightness of the light is a poor index to the mass: a given quantity of matter, finely divided, would reflect sunlight more strongly than the same quantity existing in larger particles. For the mathematical development of the subject he assumed that the material is distributed throughout a space represented by a much-flattened ellipsoid of revolution whose center is at the Sun's center, whose axis of revolution coincides more or less closely with the Sun's axis, whose polar surfaces extend twenty or thirty degrees north and south of the Sun (as viewed from the Earth), whose equatorial regions extend considerably beyond the Earth's orbit, and in which the density-distribution of materials decreases as a function both of the linear distance out from the sun and of the angular distance out from the equatorial plane of symmetry. According to these assumptions, surfaces of equal densities are concentric ellipsoidal surfaces, and the number of such ellipsoids can be increased or decreased according as the computer may desire to represent more or less closely any assumed law of density-variation within the one great spheroid. Practically, SEELIGER found that the disturbing effects on the planets are almost independent of the law of distribution of the material, as related to distance from the Sun, as far out as two thirds of the distance to *Mercury*. He made use of only two ellipsoids: One with equatorial radius 0.24 unit[1] and polar radius 0.024, of uniform density; and the other with corresponding radii 1.20 and 0.24 of uniform but much smaller density. The total mean densities determined for his volumes, on the basis of unity as the mean density of the Sun, are, respectively, 2.18×10^{-11} and 3.1×10^{-15}; and the resulting combined mass of the two ellipsoids is 3.1×10^{-7} of the Sun's mass, which is roughly twice the mass of *Mercury*. The corresponding density of mass-distribution is surprisingly low. In the inner and denser ellipsoid, the matter, if as dense as water, would occupy 1 part in 30,000,000,000 of the space; if as dense as the Earth, only 1 part in 160,000,000,000.

The reader should be cautioned against obtaining the impression that SEELIGER'S two ellipsoids represent the truth as to the law of distribution of density, for such is not the case. A very large number of ellipsoids, doubtless decreasing rapidly in density as one proceeds from the Sun outward, would be required to represent the actual law. SEELIGER found that the attractive effect of the mass inside of the ellipsoid with maximum radius 0.24 was essentially independent of the law of distribution; and for convenience in the computations he therefore assumed the density in the said ellipsoid to be uniform. A solution based upon a greater number of constitutent ellipsoids would perhaps be a slight improvement.

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[1] The distance from the Sun to the Earth being 1.00.

The logic of SEELIGER's work rests finally upon the reasonableness of his assumptions and deductions concerning the distribution and density of the zodiacal-light materials; and these are not out of harmony with the meager knowledge of the zodiacal light which we have obtained by direct observation.

In consequence of SEELIGER's results further direct observations of the zodiacal light take on renewed interest.

PLANETARY PHENOMENA FOR JULY AND AUGUST, 1909.

By MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

Full Moon	July	3,	$4^h\ 17^m$ A.M.	Full Moon	Aug.	1,	$1^h\ 14^m$ P.M.
Last Quarter	"	9,	10 58 P.M.	Last Quarter	"	8,	4 10 A.M.
New Moon	"	17,	2 45 A.M.	New Moon	"	15,	3 55 P.M.
First Quarter	"	25,	3 45 A.M.	First Quarter	"	23,	7 55 P.M.
				Full Moon	"	30,	9 8 P.M.

The Earth passes aphelion, its greatest distance from the Sun, July 3d, 7 P.M., Pacific time.

Mercury is a morning star until August 4th, when it passes superior conjunction with the Sun and becomes an evening star, remaining such until October 12th. It reaches greatest west elongation on July 7th, being on that date 21° 12′ west of the Sun. During the first half of July it rises from an hour to an hour and a quarter before sunrise, and may be seen in the morning twilight under good weather conditions, but shortly after the middle of the month it draws too near the Sun for easy observation. After becoming an evening star, in early August, it moves away from the Sun, so that by the end of the month it is well out toward greatest east elongation, but even then it sets less than one hour after sunset, and it will hardly be in reach of naked-eye observation.

Venus is an evening star, setting a little more than an hour after sunset throughout the two months' period. The interval increases only ten minutes from $1^h\ 10^m$ on July 1st to $1^h\ 20^m$ on August 31st. The apparent distance between Sun and planet increases about 12°, and this would mean an increase of about forty-eight minutes in the interval between the setting of the two bodies, but for the fact that *Venus* is moving southward much faster than the Sun, and this relative southward motion of the planet nearly counterbalances the gain due to increased distance. *Venus* and *Jupiter* are in very close conjunction on the night of August 11th-12th. The nearest approach is 12′, less than half of the apparent diameter of the Moon. This occurs about 11 P.M., Pacific time, some hours after the planets have set for all points in the United States; but the planets will be very close together on the evening of that date.

Mars is gradually drawing near opposition. It rises shortly before $11^h\ 30^m$ on July 1st, and at a little after 8^h P.M. on August 31st. It moves eastward and northward about 15° among the stars with gradually diminishing speed, until August 23d; it then begins its retrograde, westward, motion but moves only about half a degree before the end of the month. It is in the constellation *Pisces* and passes the vernal equinox on the afternoon of July 15th. It does not cross the celestial equator at that time, as it is then in the southern part of its orbit, and is about 5° south of the ecliptic. *Mars* passes perihelion on August 13th, more than a month before opposition. Its distance from the Sun diminishes from 64,000,000 miles to about 38,000,000, and it will be nearly three times as bright on August 31st as it was on July 1st. In fact, it will be within about ten per cent of its maximum brightness at the end of August, and will be very conspicuous.

Jupiter is in the western sky in the evening and forms with *Venus* the most prominent feature of that part of the heavens. On July 1st it sets at about $10^h\ 40^m$ P.M. and on August 31st it sets at a little after 7^h P.M., only a little more than half an hour after sunset. During the last week in August it will be almost too near the Sun for naked-eye observation, but its great brightness may make it possible to follow it to the end of the month. During July and August it moves 11° eastward and 5° southward, from the constellation *Leo* into *Virgo*. Its close conjunction with *Venus* on August 11th has already been noted. On the night of August 24th-25th it is in conjunction with *Mercury,* the nearest approach being 40′, *Jupiter* south of *Mercury;* but both planets are then very close to the Sun, probably too close for *Mercury* to be seen, and *Jupiter* will not be an easy object.

Saturn rises half an hour after midnight on July 1st and at about 8h 30m P.M. on August 31st. It is in the eastern part of the constellation *Pisces* and moves about 1° eastward until August 6th, and then begins its westward or retrograde motion. By the end of August it will have moved about half a degree. As seen in the telescope, the rings will have widened out so that the minor axis is a little less than one fourth of the major.

Uranus comes to opposition with the Sun on the evening of July 11th and is then above the horizon the entire night. By the end of August it will set shortly after 1h A.M. It moves about 2° westward during the two months, in the eastern part of *Sagittarius,* several degrees north and east of the bowl of the "milk-dipper." No bright star is near it, and in consequence it is not easily identified by naked-eye observations.

Neptune is in conjunction with the Sun on July 9th.

ANNOUNCEMENT.

Since the great fire of April, 1906, the Astronomical Society of the Pacific has had no permanent home. With the exception of a few books which were out at the time, its entire library and other belongings were destroyed. Through the courtesy of the authorities of the University of California temporary accommodations for the beginnings of the new library were provided in the Students' Observatory at Berkeley.

The Board of Directors of the Society begs to announce that new quarters have now been obtained in San Francisco and all books, pamphlets, magazines, and other matter intended for the Society should be sent to the new address, which is Room 748 Phelan Building, San Francisco, California.

The Secretary-Treasurer, Mr. D. S. Richardson, has established daily office hours, and all mail intended for him should be sent to the address given above.

NOTES FROM PACIFIC COAST OBSERVATORIES.

THE ORBITS OF THE *CEPHEID* VARIABLES Y *SAGITTARII* AND RT *AURIGÆ*; WITH A DISCUSSION OF THE POSSIBLE CAUSES OF THIS TYPE OF STELLAR VARIATION.[1]

Of the several classes into which variable stars have been divided, only two—the Algol stars and the *Cepheid-Geminid* stars—have been shown to be distinguished by variable radial velocity. Of the nature and cause of variation in the Algol stars there can be no reasonable doubt, since all their observed phenomena point to the occurrence of stellar eclipses. The case of the *Cepheids* and *Geminids*,[2] however—I wish to treat the two classes as one—is by no means clear; and, since a number of these stars are bright enough for spectrographic work and as all so far investigated have been found to possess an orbital motion, there seems to be in this, one of the most vulnerable points for attacking the problem of stellar variability.

In order to give weight to any hypothesis regarding the cause of continuous variation, we must have a knowledge of the orbits of as many stars as possible; and to this end Director CAMPBELL has suggested several stars of this type as subjects for special work by individual observers with the great refractor. Such a piece of work is described in the present paper.

Y *SAGITTARII*.

The variability of brightness of Y *Sagittarii* was discovered by SAWYER in 1886. Since then its brightness has been observed by SAWYER, CHANDLER, YENDELL, LUIZET, and PICKERING, so that the nature and period of its variation have been established with considerable accuracy. The star's binary character was announced by CURTISS[3] in 1904.

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[1] Abstract from dissertation, published in full in *Lick Observatory Bulletin*, 151, 5, 82, 1909.

[2] These names, derived from those of the type-stars δ *Cephei* and ζ *Geminorum*, seem to have originated with Miss CLERKE. The light of both classes varies continuously, but the light-curves of the *Cepheids* are steepest on the rise from minimum to maximum, while in the *Geminids* a minimum occurs midway between two maxima.

The position for 1900.0 is $\alpha = 18^h\ 15^m.5$, $\delta = -18°\ 54'$; the light variation, according to CHANDLER, is from 6.6 magnitude to 5.8 magnitude; according to PICKERING, from 6.2 magnitude to 5.4 magnitude. The class is *Cepheid* and the spectral type approximately solar. From the observations of CHANDLER and PICKERING, covering an interval of about twelve years, the period of variation was determined as $5^d.77336$.

The spectrograms on which my orbital elements depend were obtained with the 36-inch refractor and the single-prism spectrograph ordinarily used at this observatory for stars too faint for the three-prism instrument. The comparison spectrum was furnished by the iron spark, using self-induction to eliminate the air lines. Two different kinds of plates were used—Seed's "27" and Lumière's "Sigma." The former have somewhat the finer grain, but the latter are considerably the faster. I obtained thirty-three plates in all, but owing to underexposure six of these were unfit for use.

These spectrograms exhibit the peculiarity noted by ALBRECHT[4] in the spectra of other stars of this class, the maximum intensity of the continuous spectrum being shifted toward the violet as the star's light approached a maximum and back toward the red as it approached a minimum.

The plates were measured with a Hartmann spectrocomparator.[5] As the instrument had not been used before, it was first necessary to investigate the errors of the screw. This was done in the manner described by HARTMANN[6] and the screw found to be very good, though there is indication of a slight periodic error. This error was, however, eliminated in measuring the plates by turning the screw through a half revolution between the direct and reverse measures. As a fundamental plate I used a spectrogram of the sky, photographed on a Seed "27" plate, 1908, June 29th.

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[3] *Lick Observatory Bulletin*, **3**, 31, 1904; and *Astrophysical Journal*, **22**, 274, 1905.

[4] *Lick Observatory Bulletin*, **4**, 131, 1907.

[5] See article by Dr. J. H. MOORE, *Publications A. S. P.*, **19**, 24, 1907.

[6] *Publicationen des Astrophysikalischen Observatoriums zu Potsdam*, **18**, I.

From the twenty-seven plates measured, the following elements were derived by the method of LEHMANN-FILHÉS:—

ORBITAL ELEMENTS OF Y *SAGITTARII.*

Period	$U = 5^d.77336$
Mean daily motion	$\mu = 62^\circ.3554$
Time of periastron passage	$T = 4^d.46$ after light-max.
Distance of periastron from node	$\omega = 32^\circ\ 00'$
Eccentricity	$e = 0.16$
Velocity of system	$V = +4.0^{km}$
Maximum radial velocity	$= +25.2^{km}$
Minimum radial velocity	$= -12.4^{km}$
Single amplitude of curve	$K = 19.0^{km}$
Projection of semi-major axis	$a \sin i = 1{,}485{,}000^{km}$

Within the errors of observation, there is no evidence of any irregularities in the velocity-curve, such as appear so strikingly in the curves of ζ *Geminorum*[7] and W *Sagittarii.*[8] It is noteworthy that the time interval between maximum light and maximum velocity of approach is unusually long for a variable of this class.

RT *AURIGÆ.*

The light-variability of RT *Aurigæ,* a star formerly known by FLAMSTEED's designation of 48 *Aurigæ,* was discovered by Mr. T. H. ASTBURY in March, 1905.[9] Two light-curves have been published, a preliminary one by WILLIAMS[10] and a more nearly definitive one by ASTBURY.[11]

From the discoverer's papers in the *Journal of the British Astronomical Association* are derived the following data:—

> α 1900, $6^h\ 22^m.1$; δ 1900.0, $+30^\circ\ 34'$; max., $4^m.93$; min., $5^m.91$; time from max. to min., $2^d.51$; period, $3^d.7282$; epoch of max., J. D. 2417173.36; class, *Cepheid.*

The spectral type is very approximately solar.

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[7] CAMPBELL, *Astrophysical Journal,* **13,** 90, 1901.

[8] CURTISS, *Astrophysical Journal,* **22,** 274, 1905; and *Lick Observatory Bulletin,* **3,** 36, 1904.

[9] *Journal of the British Astronomical Association,* **15,** 244, 1905.

[10] *Journal of the British Astronomical Association,* **15,** 270, 1905.

[11] *Journal of the British Astronomical Association,* **18,** 85, 1907; and **18,** 132, 1907.

The density of three preliminary plates of this star obtained with the single-prism spectrograph early in August indicated that it was bright enough for investigation with the three-prism instrument, and work with the latter was accordingly begun in September. On account of the star's faintness it was necessary to use Lumière's very rapid but coarse-grained "Sigma" plates and to open the slit much wider than is customary in using this spectrograph. Under these conditions the exposures varied from about one and three-fourths to three and one-half hours, depending upon the state of the air and the light phase of the star.

For the measurement of the plates I used the spectrocomparator and, as fundamental plate, a spectrogram of the sky was made on a Seed "27" plate, 1908, September 28th. The greater number of settings on each plate combined with the greater dispersion of the spectrograph to make the accuracy of the velocities derived from plates of this star much greater than that of the velocities determined for Y *Sagittarii*.

Twenty-six measurable plates were obtained, but in determining the velocity curve only twenty-two were used, though two of the remaining four give reasonably small residuals. Three of the unused four are much underexposed and the fourth was discarded because of its large residual, since three other plates in the same part of the curve give small residuals.

The orbital elements derived from the velocity-curve by the method of LEHMANN-FILHÉS are:—

PRELIMINARY ELEMENTS OF RT *AURIGÆ*.

Period	$U = 3^d.7282$
Mean daily motion	$\mu = 96^\circ.5615$
Time of periastron passage	$T = 3^d.40$ after light-max.
Distance of periastron from node	$\omega = 92^\circ\ 2'$
Eccentricity	$e = 0.36$
Velocity of system	$V = +21.50^{km}$
Maximum radial velocity	$= +38.54^{km}$
Minimum radial velocity	$= +4.02^{km}$
Single amplitude of curve	$K = 17.26^{km}$
Projection of semi-axis major	$a \sin i = 825{,}500^{km}$

Since publishing my original article, I have made a least-squares solution for the orbit of this star, obtaining the following final elements:—

Final Elements of RT *Aurigæ.*

Time from light-max. to periastron	$T = 3^{d}.423 \pm 0^{d}.020$
Distance of periastron from node	$\omega = 95^{\circ}.016 \pm 2^{\circ}\ 502$
Eccentricity	$e = 0.368 \pm 0.014$
Velocity of system	$V = +\ 21^{km}.434 \pm 0.399$
Maximum radial velocity	$= +\ 38^{km}.819$
Minimum radial velocity	$= +\ \ 2^{km}.895$
Single amplitude of curve	$K = 17^{km}.962 \pm 0^{km}.246$
Projection of semi-axis major	$a \sin i = 856{,}500^{km}$

By the least-squares solution the sum of the squares of the residuals was reduced from 28.69 to 22.05. The outstanding residuals are so grouped as to suggest that the orbit is not truly elliptic.

THEORIES CONCERNING THE CAUSE OF LIGHT CHANGE IN *CEPHEID* AND *GEMINID* VARIABLES.

Twelve stars whose light variation is continuous and of short period have now been investigated spectrographically with a considerable degree of completeness. We shall consider the various explanations that have been suggested as to the cause of their variability and test these explanations, as far as possible, by means of the observed facts.

The principal characteristics of stars of this type are:—

1. Their light varies without pause.
2. The amount of their light variation is usually about one magnitude.
3. Their periods are short—a few days only.
4. They are of a spectral type approximately solar; no Orion, Sirian, or Antarian stars having been found among them.
5. They seem to be found in greater numbers in certain parts of the sky, notably in the Milky Way,[13] but exhibit no tendency to form close clusters.
6. All those stars whose radial velocities have been studied have been found to be binaries, whose period of orbital revolution coincides with that of their light change.
7. The orbits, so far as determined, are all small, $a \sin i$ being $2{,}000{,}000^{km}$ or less.

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[13] Miss Clerke, *System of the Stars*, 144, 1890.

8. Their maximum light synchronizes very closely with their maximum velocity of approach, and minimum light with maximum velocity of recession.[14]
9. No case has been found in which the spectrum of more than one component has been bright enough to be recorded in the spectrograms.

The first-mentioned characteristic sharply separates these stars from stars of the Algol type, whose light-curves always contain horizontal straight lines; and the eighth shows that their variation cannot be due to occultation by the dark companion, since in that case minimum must occur at inferior conjunction. The third property makes it imperative that a theory, to be successful, should connect the light variation with the orbital revolution.

In his discussion of the orbit of *ζ Geminorum*,[15] Dr. CAMPBELL suggested tidal disturbances[16] in an atmosphere surrounding the brighter component, due to the gravitational attraction of the darker; and explained the fact that minimum light occurs soon after periastron passage by supposing a reduction of brightness due to a sudden expansion of the gases of the atmosphere under the influence of maximum tidal action when near periastron. That maximum light, instead of minimum, occurs soon after the nearest approach of the two components in the cases of *η Aquilæ* and *δ Cephei,* he thought might be explained by the greater difference of tidal action in different parts of the orbits of these stars, owing to their greater eccentricity.

At that time, however, the orbits of only three stars of this class had been determined, and in the light of subsequent research on other variables of this type, there are serious objections to the general application of this theory.

First, no general relation seems to hold between the time of periastron passage and the time of greatest brilliancy.

Second, the theory in no way explains ALBRECHT's discovery of the time relation between maximum light and maximum velocity of approach.

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[14] ALBRECHT, *Lick Observatory Bulletin*, **4**, 138, 1907.

[15] *Astrophysical Journal*, **13**, 90, 1901.

[16] The tidal theory appears to have been first suggested by ROBERTS, of South Africa, *Astrophysical Journal*, **2**, 283, 1895.

Third, no increase in the range of brightness variation is found in the case of stars having orbits of greater eccentricity.

Moreover, if the tidal disturbance takes place in the bright star's atmosphere, we should expect to find bright lines in the spectrum, and this has never been observed. If, on the contrary, the disturbance occurs in the denser part of the body, it seems unlikely that the star should lose perceptibly in brilliancy during the few days that elapse before it is again subjected to maximum tidal action.

However, despite these obstacles to making tidal action a chief basis for explaining the light variations of these objects, it is very probable that this action does have a profound influence on the behavior of the system.

A second hypothesis for explaining the variation of stars of this type is that of a resisting medium in which the binary system is supposed to be enveloped, and the impact of whose particles causes the star's advancing side to become heated. This idea was first published by Dr. R. H. CURTISS[17] and has been somewhat elaborated upon by Professor F. H. LOUD.[18] The impact of the particles of a resisting medium of nebulous or meteoric matter might cause variation in a star's light in two ways—first, as the star revolved in its orbit, if it moved at different times with different speed or through portions of the medium having different densities, there would result a difference in the actual rate of emission of light; second, if the star moved like the Moon, keeping always the same face towards its dark companion, the preceding face would, by the impact of particles, be kept constantly hotter than the following side, and, as the star rotated, first the darker and then the brighter side would be presented to the observer.

The hypothesis of a resisting medium has many things in its favor, but chiefly the fact that it accounts for the synchronism of maximum light and minimum positive velocity.

That the variation of the star's light can be accounted for by a change in the rate of light emission is rendered improbable by the following facts:—

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[17] *Lick Observatory Bulletin*, **3**, 40, 1904; and *Astrophysical Journal*, **20**, 186, 1904.

[18] *Astrophysical Journal*, **26**, 369, 1907.

1. In order that the actual emission of light may vary, the star must cool perceptibly during the few days which elapse between successive passages through those parts of the orbit where the bombardment is most fierce. This would necessitate that the disturbance take place only in the outer and rarer parts of the star's atmosphere—a fact which is contradicted by the character of the spectrum.
2. No greater range of light variation is observed in stars having highly eccentric orbits than in those whose orbits are only slightly eccentric, and in general, there is no marked outburst of light when the star is near periastron.

If we make use of the hypothesis of a resisting medium, we must therefore restrict it to the case where the period of rotation of the bright star is equal, or nearly equal, to that of its revolution. Professor LOUD's ideas may, I think, be briefly summed up as follows: Since the star's binary character is betrayed, not by a doubling of the lines but by their periodic shift, one component only is luminous; its light is due to the bombardment of its surface by particles of the medium through which it moves, and to which its companion, since it is non-luminous, must be relatively at rest. The distance between the two components is so small that tidal action tends strongly to equalize the periods of rotation and revolution of the bright satellite; but, owing to the resistance imposed upon its motion, the satellite moves upon an ever-diminishing spiral, its period of revolution shortens, and therefore that period is always a little shorter than the period of rotation. The effect of this lag of the rotation is to cause the heated area on the satellite, produced by meteoric bombardment, to become unsymmetrical, the point of greatest heat moving slowly along the equator into colder regions, leaving behind it a slowly cooling band. To an observer, then, whose line of sight is not perpendicular to the plane of the orbit, the star's light would vary continuously, but the time-interval from minimum to maximum would be shorter than that from maximum to minimum—a well-known distinguishing feature of the light-curves of many variables of this type. Those cases where the asymmetry in the light-curve is reversed or where, as in ζ *Geminorum,* it does not exist, he explains by assuming that the rate of rotation is more rapid than, or equal to, that of revolution. Irregularities in the light-curves are explained by the separate or joint action of three causes: Ellipticity of the orbit, producing greater speed near periastron; "libration," or the optical effect of variation of angular speed in revolution owing to the orbit's eccentricity, while the rotation rate is constant; and variations in the density of the medium.

In the majority of the variables of this class whose orbits are known, the light maximum occurs a little before maximum velocity of approach—instead of a little after or exactly simultaneous with it, as we should expect on this hypothesis. This LOUD explains by supposing that the meteoric bombardment induces in some cases not only an increase of light but an increase of absorption, so that we do not at once get the full effect of the maximum light—a supposition whose truth we cannot disprove, though it seems to have little to sustain it.

Whatever the manner in which the impact of meteoric particles may produce the variation of light, it is certain that the work done by the star in imparting momentum to the meteors must tend to shorten the period of revolution; and perhaps a crucial test of the hypothesis may be found in the calculation of the relations between this shortening and the quantity of energy emitted in the forms of light and radiant heat.

In my original article I accordingly calculated these relations and found that, for a star moving in a circular orbit with a period of six days and a speed of 20^{km} per second, through a flock of meteors sufficiently dense to produce by their bombardment a variation in the star's light of 0.8 magnitude, the shortening of the star's period would be seventeen seconds per year. Only one star of this type has been observed to possess a secularly diminishing period. This star is δ *Cephei,* whose period, according to CHANDLER, shortens by only $0^s.108$ per year, the period itself being between five and six days, and the variation in brightness 0.9 magnitude.

It is true that, between stars situated so close together as are the *Cepheid* variables, tidal action might be very strong and that by its tendency to lengthen the period it might counteract the tendency of the resisting medium to shorten it. It would seem strange, however, that in so many cases the two effects should so exactly balance that no change in either direction could be detected. Besides, there are many binaries —chiefly variables of the Algol type—whose periods are as short and whose components are as closely situated as are those of the *Cepheids,* but in whose periods no secular change has been detected. In fact, the only Algol variable in whose period CHANDLER notes any secular change is, as we have seen, *U Coronæ,* whose period is shortening but which gives no evidence of light variations of the δ *Cephei* or continuous type. It seems possible, indeed, that among the *Cepheid* stars tidal action has arrived at the stage where both bodies are drawn into prolate ellipsoids and each keeps always the same face towards the other, so that the period has no longer any tendency to increase.

Aside from the change of a star's period, there are other considerations which militate against the hypothesis of bombardment as an explanation of continuous light variation. For example, since these stars move at fairly high speed in small orbits, the invisible companion must be a body of considerable mass as compared with the star that we see. Why, then, if the impact of meteoric bodies is sufficient to produce a large percentage of the radiation of one component, does it not make the other also visible? The meteoric bodies cannot remain at rest relative to either of the components, so we must suppose those particles which the bright star picks up to be moving in orbits about the dark component. If these orbits have the same eccentricity as that of the bright star and if the bodies are moving in the same direction as the star, they must move with nearly the same speed and we can have no violent collisions; if they cross the star's orbit at a large angle, then the star's brightest point will not be in front, but at the side; and if they move in retrograde orbits nearly coincident with the orbit of the star, the star should, in a comparatively few revolutions, collect all the meteors near its path, so that all bombardment would cease.

The question now arises whether, in the present state of our knowledge, a more satisfactory hypothesis for explaining the phenomena of these stars can be found. We have seen that it is unlikely that the variation in brightness can be due to an actual change in the rate of light emission, since in that case the character of the spectrum should change radically during the interval between maximum and minimum. It is clear also that the variation cannot be produced by rotation combined with the greater heating of the star's advancing side by the impact of meteoric particles. Since, however, the character of the spectrum indicates the presence of an absorbing envelope about the luminous body of the star, the change in brilliancy may be due to a variation of absorption; and it is to an hypothesis based on this assumption that I now wish to direct attention.

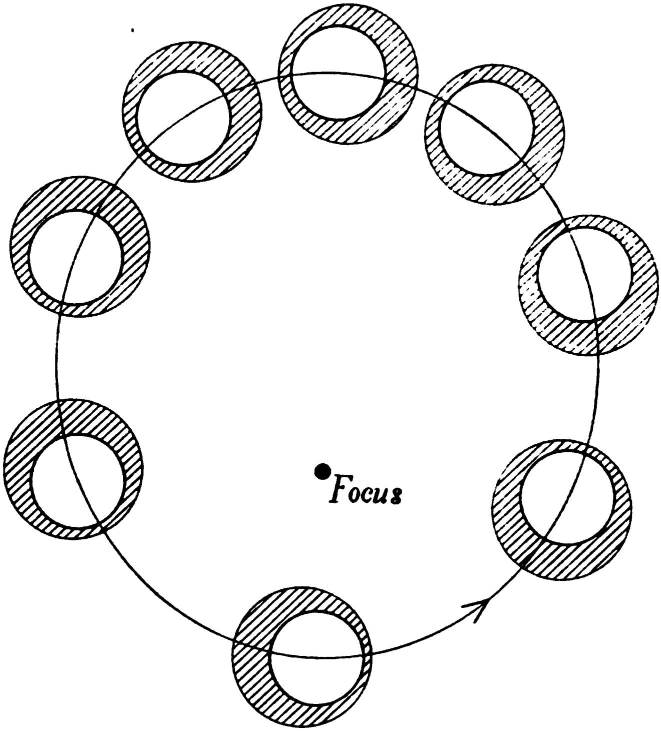
The idea that the variation of light is due to a variation of absorption gains in weight when we recall the similarity between the light- and velocity-curves of these stars, which has been well known since the first orbits were determined and which is especially striking in the case of W *Sagittarii*. The light-curves of stars are ordinarily drawn with ordinates measured in terms of "magnitudes" or other units which express, not the actual amount of light, but the intensity of the observer's sensation, which is proportional to the logarithm of the light. Hence, the similarity of the light-curves and the velocity-curves indicates that the logarithm of the light, and not the light itself, is proportional to the radial velocity. Now, for an absorbing medium of uniform density, the logarithm of the light varies as the thickness, the law of absorption being

$$\log \frac{E}{I} = -\beta x,$$

where x is the thickness of medium traversed, β the coefficient of absorption, and E and I the respective intensities of the emergent and incident light. Therefore, the star's light variation may be explained by assuming an absorbing atmosphere whose depth on the side toward the observer is, within appropriate limits, inversely proportional to the component of the velocity in that direction.

The principal requirements of the case may be met if we suppose a very rare envelope of nebulous matter to surround the darker star of the pair, and that the atmosphere of the brighter component is brushed backward by the friction of this medium so that its depth on the advancing side is less than that on the following. It seems to me to be possible that the Sun's corona is an envelope like this and that coronæ of equal or perhaps greater density may surround all stars of the solar and more advanced types. The orbits of *Cepheid* stars are probably all very much smaller than the orbit of *Mercury* ($a \sin i$ averages about 1,500,000^{km}, while *Mercury's* mean distance is 58,000,000^{km}), and it may be that at a distance from the Sun itself equal to the mean distance between the average *Cepheid* pair the corona would be dense enough to produce the observed effects. If we suppose the absorbing atmosphere of the lucid star to be of low specific gravity, then the envelope of the darker component need not be dense enough to produce by its friction a perceptible shortening of the period.

The shape assumed by the moving star's atmosphere in different parts of the orbit is rudely represented in the figure. The ellipse in the figure has an eccentricity of about one third, which is near the average eccentricity of the *Cepheid* orbits. The atmosphere is represented as spherical but eccentrically placed with regard to a moving spherical star—a condition which is of course only approximately realized. From the figure it is easy to see that maximum light will always occur near the time of minimum positive velocity, and minimum light near maximum positive velocity. The synchronism should be exact if there are no disturbing influences and if the orbit is circular or the resistance varies exactly as the inverse first power of the velocity; for then the depth of the star's atmosphere, measured in any direction, should be inversely proportional to the resolved part of the velocity in that direction. If, however, the resistance varies inversely as the velocity raised to any higher power than the first, and if the orbit be eccentric, then exact synchronism will not hold. In that case, for values of ω between 0° and 180°, the body will be approaching periastron and the distortion of the atmosphere increasing when it is receding from the observer, and *vice versa;* so that maximum



light should occur a little before velocity minimum and minimum light a little after velocity maximum. For values of ω between 180° and 360°, these conditions should be reversed. An inspection of Table III shows a tendency towards fulfillment of this rule, though there are several exceptions. These may be due to several causes, such as inaccuracy of the orbits or of the photometric observations, inequality of density in different parts of the nebulous envelope, and inequalities of brightness on different parts of the star's surface. In several cases the disagreement in the epochs of maximum or minimum light according to different observers would indicate an uncertainty in those epochs sufficient to account for the exceptions to our rule.

The range of light variation will depend on two factors: the specific absorbing power of the bright star's atmosphere,

TABLE III.—VARIABLE STARS OF THE *CEPHEID* AND *GEMINID* TYPES WHICH ARE KNOWN TO BE BINARY.

Star	α 1900.0	δ 1900.0	Max.	Min.	V km	V′ km	K km	e	ω	T	U	a sin i
RT *Aurigæ*	$6^h\ 22^m.1$	+30° 34′	4.9	5.9	+21.5	+11.7	17.3	0.36	92°.0	$3^d.4$	$3^d.73$	$826{,}000^{km}$
ζ *Geminorum*	6 58 .2	+20 43	3.7	4.3	+ 6.8	− 5.7	13.2	0.22	333	6 .4	10 .15	1,798,000
l *Carinæ*	9 42 .5	−62 3	3.6	5.0				0.3±			35 .53	
X *Sagittarii*	17 41 .3	−27 48	4.4	5.0	−15 ±	− 5 ±	15.8 ±	0.45 ±	90 .4 ±	6 .3	7 .01	
Y *Ophiuchi*	17 47 .3	− 6 7	6.2	7.0	− 5.0	+10.8	8.5	0.10	209 .2	2 .6	17 .12	1,999,000
W *Sagittarii*	17 58 .6	−29 35	4.6	5.4	−28.6	−18.6	19.5	0.32	70 .0	6 .7	7 .59	1,930,000
Y *Sagittarii*	18 15 .5	−18 54	5.8	6.6	+ 4.0	+17.0	19.0	0.16	32 .0	4 .5	5 .77	1,485,000
κ *Pavonis*	18 46 .6	−67 21	3.8	5.2							9 .09	
U *Aquilæ*	19 24 .0	− 7 15	6.2	6.9							7 .02	
SU *Cygni*	19 40 .8	+29 1	6.5	7.2	−33.4	−14.2	25 ±	0.21	345 .8	2 .5	3 .85	1,350,000
η *Aquilæ*	19 47 .4	+ 0 45	3.7	4.5	−14.2	+ 4.2	20.6	0.49	68 .9	6 .2	7 .18	1,545,000
S *Sagittæ*	19 51 .5	+16 22	5.4	6.1	−12.5	+ 5.8	19 ±	0.35	69 .9	1 .3	8 .38	2,000,000
T *Vulpeculæ*	20 47 .2	+27 52	5.5	6.5	− 1.3	+15.9	17.6	0.43	111	3 .8	4 .44	969,000
δ *Cephei*	22 25 .4	+57 54	3.7	4.6	−18	− 5	20.5	0.46	272 .3	4 .8	5 .37	1,300,000

TABLE III (*Continued*).—VARIABLE STARS OF THE *CEPHEID* AND *GEMINID* TYPES WHICH ARE KNOWN TO BE BINARY.

Star.	Min._v–Max._l	Max._v–Min._l	Discoverer of Light-Variability.	Discoverer of Binary Character.	Authority for elements of Orbit.
RT *Aurigæ*	$+0^d.16$	$+0^d.36$	ASTBURY	DUNCAN	DUNCAN, *Lick Obsy. Bull.*, **5**, 86, 1909.
ζ *Geminorum*	-0.2		SCHMIDT	CAMPBELL BÉLOPOLSKY	CAMPBELL, *Astroph. Jour.*, **13**, 90, 1901.
l *Carinæ*	$-2\frac{1}{2}\pm$		GOULD	WRIGHT	ALBRECHT, unpublished.
X *Sagittarii*	$-0.2\pm$	$-1.3\pm$	SCHMIDT	SLIPHER	MOORE, *Lick Obsy. Bull.*, **5**, 111, 1909.
Y *Ophiuchi*	-1.3	$+0.5\pm$	SAWYER	ALBRECHT	ALBRECHT, *Lick Obsy. Bull*, **4**, 132, 1907.
W *Sagittarii*	-0.1	$+0.2$	SCHMIDT	CURTISS	CURTISS, *Lick Obsy. Bull.*, **3**, 36, 1904.
Y *Sagittarii*	$+0.78$	$+0.1\pm$	SAWYER	CURTISS	DUNCAN, *Lick Obsy. Bull.*, **5**, 85, 1909.
κ *Pavonis*			THOME	WRIGHT	
U *Aquilæ*	-0.5		SAWYER	ALBRECHT	
SU *Cygni*	$+0.22$	$+0.02$	MÜLLER and KEMPF	MADDRILL	MADDRILL, unpublished.
η *Aquilæ*	-0.2		PIGOTT	BÉLOPOLSKY	WRIGHT, *Astroph. Jour.*, **9**, 59, 1899.
S *Sagittæ*	-0.22	$+0.4$	GORE	CURTISS	MADDRILL, unpublished.
T *Vulpeculæ*	$+0.3$	$+0.1$	SAWYER	FROST	ALBRECHT, *Lick Obsy. Bull.*, **4**, 135, 1907.
δ *Cephei*			GOODRICKE	BÉLOPOLSKY	BÉLOPOLSKY, *Astroph. Jour.*, **1**, 160, 1894.

and the ratio of depth of that atmosphere on the front and rear sides of the star; and the latter in turn will depend also on two factors: the relative densities of the atmosphere and the nebulous envelope through which it is dragged, and the speed of the star. To produce a variation of 0.8 magnitude—*i. e.* in order that the light at maximum shall be double that at minimum, it is of course necessary that the atmosphere on the following side absorb at least half the light emanating from that side of the star, and even with that degree of absorbing power the front side of the star must be laid wholly bare. If, however, the atmosphere on the following side absorb three fourths of the incident light, it need be only twice as deep as that on the preceding side in order to produce the above variation. The atmosphere of the Sun, according to LANGLEY, absorbs from one half to four fifths of the light passing normally through it, the absorption being greatest in the blue end of the spectrum.

Dr. ALBRECHT'S discovery that the maximum intensity of the spectrum of a *Cepheid* variable is shifted toward the violet as the star approaches maximum and redwards again as minimum approaches, is in agreement with the hypothesis of absorption. HALE and ADAMS[19] find a more distinct example of the same phenomenon in their comparison of the spectra of the center and limb of the Sun, in that it was necessary to expose eight to ten times as long at the limb as at the center for the violet, but only four or five times as long at the limb as at the center for the red.

It will be of interest to compare spectrograms of the same star made at maximum and minimum to find out if there be any such changes as HALE and ADAMS found in the solar spectrum in moving from the Sun's center to its limb. None of the plates obtained with the single-prism instrument lends itself to this purpose on account of the low dispersion, and the spectrograms that I obtained of RT *Auriga* were taken with too wide a slit.

By an inspection of Professor WRIGHT'S plates of η *Aquilæ*, made with the 3-prism Mills spectrograph, Dr. ALBRECHT[20] found variations in the position of spectral lines as the star's light phase changed from maximum to minimum, which correspond to the changes which he observed in passing from one spectral type of star to another;[21] and the appearance at light minimum corresponds to that of an older-type spectrum, thus indicating an increase of absorption at minimum.

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[19] *Contributions from Mount Wilson Solar Observatory*, No. 17.

[20] *Lick Observatory Bulletin*, **4**, 131, 1907.

If the nebulous envelope which I have supposed to exist about the darker star be similar to the Sun's corona, we may expect the form of the light-curve to vary slightly in a period of several years, since the form of the corona, and hence the relative density of its different parts, vary in a similar period. Such a change has been suspected by CURTISS in the case of W *Sagittarii,* and may to some extent account for the dissimilarity of the light-curves of other stars, derived from sets of observations made several years apart. However, in the present state of photometric work, this question cannot be decided.

In Table III is given a list of such variable stars of the *δ Cephei* and *ζ Geminorum* types as are known to possess a variable radial velocity, together with their orbital elements and such other data as I have thought might be of interest. Column one contains the star's name, columns two and three its position for 1900.0, and the two following columns its magnitude at maximum and minimum brilliancy. V is the velocity of the binary system relative to the Sun, and V' that velocity corrected for the solar motion, or the system's velocity relative to the system of brighter stars about us. K is the single amplitude of the velocity-curve, e the eccentricity, ω the argument of periastron measured in the direction of orbital motion from a fundamental plane at right angles to the sight line, T the time of periastron passage in days after light maximum, $\dot{U}$ the period of orbital revolution in days, and $a \sin i$ the orthographic projection of the semi-axis major upon the YZ plane. The fourteenth column gives the interval in days from maximum light to minimum velocity of recession, and the fifteenth the interval from minimum light to maximum velocity of recession. The last three columns give the names of the discoverer of light variability, the discoverer of variability of radial velocity, and the authority for the orbital elements given.

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[21] *Lick Observatory Bulletin,* 4, 90-95, 1906.

It is with pleasure that I acknowledge my indebtedness to Director CAMPBELL, who placed at my disposal the necessary instruments, and who also aided me with advice and encouragement; to Messrs. WRIGHT, MOORE, and ALBRECHT for various suggestions in discussing the hypotheses regarding stellar variability; to Professor CRAWFORD, of Berkeley, who verified the mathematical work; and to Misses HOBE and ALLEN, who performed a part of the computation.

J. C. DUNCAN.

MT. HAMILTON, May 25, 1909.

THE ORBIT OF THE *CEPHEID* VARIABLE STAR X *SAGITTARII*.[1]

The variable brightness of X *Sagittarii* was discovered by SCHMIDT in 1886. Its variability was soon recognized to be similar in type to that of δ *Cephei*, characterized by a regular and continuous change in light, and the inequality of the intervals from maximum to minimum and minimum to maximum.

The variable radial velocity of X *Sagittarii* was detected by Mr. V. M. SLIPHER[2] from his measures of the plates of June 19 and 22, 1904. A series of spectrograms of this star was secured at the Lick Observatory in August, September, and October, 1904, with the one-prism spectrograph equipped with a light 60° prism.[3] The period being so nearly commensurable with a day, these observations were sufficient to determine only seven points of the curve. It was then necessary to wait until the summer of 1905 before observations at intermediate points of the curve could be secured. When the 1904 and 1905 series were measured and reduced by the method described by Mr. R. H. CURTISS[4] it was found that the accordance of the observations, using all of the plates, was not satisfactory, due to differences in exposure, combined with the poor character of the lines in the star spectrum. Accordingly a series of ten plates was secured, in the summer of 1908, with the Mills spectrograph (three-prism), using a slit-width of 0.05^{mm} (which is about 0.010^{mm} to $.014^{mm}$ wider than is used in the regular observing with this instrument), and the very rapid Lumière Σ plates. With the exception of one plate, which was badly underexposed, the three-prism series was capable of accurate measurement.

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[1] A detailed account of this investigation will be found in *Lick Observatory Bulletin*, 157, **5**, 111, 1909.

[2] *Lowell Observatory Bulletin*, **11**, 1904, and *Astrophysical Journal*, **20**, 146, 1904.

[3] For a description of the one-prism instrument, see Mr. R. H. CURTISS's article, *Lick Observatory Bulletin*, **3**, 19, 1904.

[4] *l. c.*

The final procedure was to measure only the best plates taken with one prism (the 1904 and 1905 series) and the new series of three-prism plates.

After a number of trials the following elements were decided upon as giving the best representation of the observations:

$U = 7.01185$ days (assumed)
$\mu = 51^{\circ}.342$
$e = 0.40$
$\omega = 93^{\circ}.65$
$T =$ J. D. 2416723.05
$a \sin i = 1{,}334{,}000^{km}$
$V =$ velocity of system $= -13.50^{km}$

The epoch of greatest velocity of approach is 0.28 day later than the time of light maximum. The close agreement of the times of light maximum and of the greatest velocity of approach is a fundamental characteristic of all variables of the *Cepheid* type, as pointed out by Mr. ALBRECHT.[5] There seems to be no close connection in the case of X *Sagittarii* between the time of minimum light and that of the greatest velocity of recession, the minimum in the light-curve preceding the time of greatest positive velocity by about 1.7 days. This connection does not appear, however, to be such a close one as that for maximum light and greatest negative velocity in the case of other *Cepheid* variables. The smooth character of the light- and velocity-curves of X *Sagittarii* is worthy of note. Evidently if any irregularities exist in either, they are quite small.

J. H. MOORE.

MT. HAMILTON, April 19, 1909.

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[5] *Lick Observatory Bulletin*, **4**, 130, 1907.

THE SPECTRA OF SOME SPIRAL NEBULÆ AND GLOBULAR STAR CLUSTERS.[1]

This investigation was undertaken to test the correctness of the statement frequently found in astronomical literature that the spectra of the spiral nebulæ are continuous, and to increase our knowledge of these spectra in any manner possible. A few globular star clusters were added to the program for reasons given below.

There are but two published observations, as far as known, which cast any doubt on the continuous character of the spectra of spiral nebulæ—one by SCHEINER[2] and the other by HUGGINS,[3] both of whom worked on the *Andromeda* nebula. Each of these observers obtained a spectrogram showing absorption lines: the former, lines corresponding to G (λ 4308) and H (λ 3969) of the solar spectrum; the latter, the G, H, and K (λ 3934) lines, with some others not named. The spectrogram by SCHEINER was probably faint and there may be some doubt as to its interpretation, for the late Director VOGEL, who presumably saw the plate, when revising NEWCOMB-ENGLEMANN'S *Populäre Astronomie* several years later, said on page 577: "Selbst über das Spektrum des bekannten Andromedanebels ist nichts weiter bekannt, als dass er nicht das sonst bei Nebeln gewöhnlich vorkommende Gasspectrum zeigt." HUGGINS does not seem to think his plate entirely free from suspicion, for he says:[4] "The photograph . . . we had put aside . . . as probably vitiated, in some unknown way, by the coming in of direct solar light, or of moonlight." The basis for this suspicion is due to the fact that an overexposed solar spectrum was imprinted on the same plate for comparison. HUGGINS also observed visually some bright lines in the spectrum of this nebula.

These two photographic observations agree in showing absorption lines present in this nebular spectrum; but, judging from the circumstances as noted, the evidence can hardly be called conclusive.

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[1] Abstract of *Lick Observatory Bulletin*, No. 149.

[2] *Astronomische Nachrichten*, **148**, 325, 1899.

[3] *Atlas of Representative Stellar Spectra*, p. 119, 1899.

[4] *Atlas of Representative Stellar Spectra*, p. 126.

The telescope used in the present investigation was the Crossley reflector.[5] Some preliminary work by the writer, in the summer of 1907, with this telescope and a small quartz spectrograph, on the *Andromeda* nebula promised interesting results. Accordingly a special spectrograph[6] was designed for efficiency in observing such faint objects, using optical and other materials in part already on hand.

The extremely feeble intensity of the light of the spiral nebulæ, even the very brightest, is hard to realize. A comparison of stellar spectrograms taken with the instruments used in this investigation and those made with the Mills spectrograph attached to the 36-inch refractor shows that the latter requires from twenty to thirty times as long an exposure as the former to obtain spectrograms of the same density, using the same slit-width in both cases.[7] Assuming the ratio of the exposures as 1 :25, and using a slit-width of 0.08^{mm} and Lumière Σ plates, it would take an exposure of 450 hours with the Mills spectrograph to obtain a satisfactory plate of the brightest part of the *Andromeda* nebula, which is one of the brightest of the spirals. This statement is based on plate 45, which is of about the proper density. It is further based on the favorable assumption that for a spectrum of given intensity the exposure time varies inversely as the intensity of the light falling on the plate. As is well known, this is not the case, so that a 500-hour exposure would probably be nearer the truth. Under similar conditions a plate of *Arcturus,* which is of the same spectral type, could be secured with the Mills spectrograph in less than two minutes.

The results of this preliminary investigation may be summed up in the statement: No spiral nebula investigated has a truly continuous spectrum. While this may be a step in advance, nevertheless it is wholly inadequate to answer the question as to the real nature of these interesting objects which the work of KEELER brought so prominently before the astronomical world. Their spectra vary from those having principally bright lines such as are found in the gaseous nebulæ to those containing only absorption lines of the solar type.

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[5] For a description of this telescope with its present mounting, see *Lick Observatory Bulletin,* **3**, 124, 1905.

[6] For a description of this spectrograph, an account of the methods of observing, and of the details of the results obtained, the reader is referred to the original paper.

[7] The purity, of course, would be vastly different owing both to the difference in focal lengths of the respective collimator lenses and the great difference in dispersion.

In trying to interpret these results it must be remembered that the spectrograms obtained record only the spectra of the denser central portions of the nebulæ. In the case of the *Andromeda* nebula this amounts to five minutes of arc. Then, too, the very low dispersion of the spectrograph used undoubtedly masks much that is of fundamental importance. Whether the spiral arms will give the same spectrum as the central portion is a question which will be difficult to answer with present appliances.

Careful consideration has been given to various hypotheses to account for the character of the spectra photographed. Only one hypothesis seems at all tenable, and serious objections can be advanced against this one. It may be termed the "star-cluster" theory, reached by the following considerations.

The only known sources of continuous spectra are luminous solids, liquids, very dense gases, or possibly masses of gas of great thickness. To produce bright lines or bands we require gases or vapors rendered luminous by heat, electric discharges or chemical change, or substances made to fluoresce by energy supplied by some external agency. For absorption lines or bands to be present the necessary condition is an absorbing medium, usually of a gaseous nature, between a source of continuous radiation and the observer. These are, for the most part, well established experimental facts.

The primary or fundamental part of the spectra of the spiral nebulæ is a continuous background. This is interrupted by absorption lines, and superimposed upon it in some cases are bright lines or bands. The matter producing the lines, bright or dark, must be assumed to lie between the source of continuous radiation and the observer. Hence we conclude this source to be surrounded by a gaseous envelope, of physical condition varying in the different nebulæ and corresponding to the various spectra obtained. The only celestial bodies of this type with which we are acquainted are the stars.

The hypothesis that the central portion of a nebula like the famous one in *Andromeda* is a single star may be rejected at once unless we wish to modify greatly the commonly accepted ideas as to what constitutes a star. Assuming, however, an unresolved star cluster consisting of stars mainly of solar type we would seem to have a sufficient explanation of the spectrograms of the *Andromeda* nebula. But the question arises: Is it reasonable to assume that in a condensed cluster we should have stars of one spectral type strongly predominating?

In seeking an answer to this question I have found but two references to observations of the spectra of known dense star clusters. These are not sufficiently definite to settle the matter. HUGGINS,[8] in reporting an observation on the great cluster in *Hercules,* says: "Spectrum of central blaze continuous. Spectrum ends abruptly in the orange. The light of the brighter part is not uniform; probably it is crossed by bright lines or lines of absorption." VOGEL[9] likewise observed this cluster and writes as follows: "Der bekannte Sternhaufen im *Hercules* zeigte ein sehr schwaches continuirliches Spectrum, welches sich von ca. 620 bis 450 Milliontel Millimeter verfolgen liess. In demselben waren einige dunkle Streifen zu erkennen, konnten aber wegen zu grosser Lichtschwäche nicht gemessen werden."

It was accordingly necessary to investigate some known star clusters. From the Crossley negatives three dense clusters were selected for trial—N. G. C. 6205, 7078, and 7089. The first, the famous cluster in *Hercules,* gave evidence of containing stars of different spectral types, while the other two gave F-type spectra only. Photographs show clusters such as these to be made up of two groups of stars,[10] the one of magnitudes 11 to 13 and the other of about magnitude 16. The brighter group was probably the only one giving the spectrograms. If we could view such a cluster from a distance so great that it could not be resolved into its component stars there is no question but that it would continue to give such spectrograms as have been described. We thus have the question as to whether clusters can be found in which stars of one spectral type predominate answered in the affirmative.

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[8] *Philosophical Transactions,* **156,** 389, 1866.

[9] *Astronomische Nachrichten,* **78,** 245, 1871.

[10] *Lick Observatory Bulletin,* **3,** 49, 1904, and *Astrophysical Journal,* **20,** 354, 1904.

The "star cluster" interpretation of the results obtained stands or falls by the question of parallax. It does not seem reasonable to assume stars that should be many times smaller than the Sun. We also require the cluster to be at such a distance that it cannot be resolved. Now the only determination of the parallax of a spiral nebula that the writer has been able to find is that of the *Andromeda* nebula by BOHLIN.[11] He finds this to be $0''.17$. His result rests on two separate determinations, each of which gave positive values for the parallax both in α and δ. The result is therefore entitled to some confidence. If, now, the parallax of the *Andromeda* nebula is of this order of magnitude, the "star-cluster" theory, at least for this particular object, is not very satisfactory. For, assuming this parallax; a surface brilliancy of the component stars equal to that of the Sun; and a ratio of brightness of the central portion of this nebula to that of the Moon of 1/180,000 (derived from Crossley negatives): a simple computation shows that if the stars are so closely packed as to be irresolvable their dimensions are of the order of the asteroids; while if assumed only as large as *Jupiter* they would appear some seconds of arc apart. This is not found to be the case. The "star-cluster" theory, however, seems to be the only one that can at all adequately explain the spectrum obtained, and another determination of the parallax, preferably by another observer with a different instrument, would be of great interest.

The theory as given above is not a new one, but with the exception of the work of SCHEINER and HUGGINS on the *Andromeda* nebula there were no facts, so far as the writer has been able to find, to support it. Even now the material is very meager and more questions have been raised than answered. We still know nothing concerning the spectra of the spiral arms and little or no light is shed on the fundamental questions of the origin of the spiral nebulæ, their relations among themselves, and to other stellar objects. These questions must be left for the future.[1]

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[11] *Astr. Iaktt. o. Unders. A Stockholms Obs.*, **8**, No. 4, 66, 1907.

E. A. FATH.

MT. HAMILTON, December, 1908.

NOTE ON THE CLASSIFICATION OF DOUBLE STARS.

Lick Observatory Bulletin, Number 158, contains another list of one hundred new double stars discovered and measured with the 36-inch telescope. This list brings the total number of my published discoveries to two thousand. Arranging these stars according to their angular separation, we have the following table:—

Distance	No. of Pairs	Percentage
0″.25 or less	182	9.10
0 .26 to 0″.50	444	22.20
0 .51 to 1 .00	400	20.00
1 .01 to 2 .00	450	22.50
2 .01 to 5 .00	511	25.55
5 .01 or greater	13	0.65
	2000	100.00

From this table it appears that more than one half (51.3%) of the stars listed belong to STRUVE's Class I (distance 1″ or less), and that nearly three fourths (73.8%) fall within the 2″ limit. The thirteen pairs which exceed the limit 5″.0 have components whose difference in brightness averages 5.7 magnitudes. In only three cases does the angular separation exceed 5″.2. Though the program of my survey contemplates the systematic examination of the stars only to the magnitude 9.0, inclusive, it is inevitable that fainter stars should from time to time be brought into the field of the telescope. In this way many fainter pairs have been discovered, but, in general, only the very close ones have been listed. In all, I estimate that considerably less than 10 per cent of the pairs published have components whose combined brightness falls below 9.0 B. D. magnitude.

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[1] The publication of the above paper was unavoidably delayed. Since it was written Professor BARNARD has published the results of a photographic investigation of the *Hercules* cluster in the *Astrophysical Journal*, **29**, 72, 1909. He finds that this cluster is composed of stars of different spectral types. The spectrographic results obtained by the writer are in agreement with this.

E. A. FATH.

March, 1909.

Excluding the stars south of — 30° Declination, I find by examining the various double-star catalogues that there are about 7,500 known pairs with measured distances of 5″ or less. This is an estimate only, but as care was taken to include all published lists and to make the estimates liberal I think the number given is certainly large enough. Of this number about 4,400 have distances under 2″, and 2,550 of these are under 1″. These figures are more nearly exact than the general total. The survey now in progress at this observatory has contributed 3,300, 2,460, and 1,700, respectively, to these totals. Nearly 60 per cent, therefore of the 7,500 pairs under 5″ are under 2″, and this percentage will be raised at the completion of our survey, for nearly 75 per cent of the 3,300 pairs already found here belong to the closer class. In other words, the actual number of very close double stars (distances under 2″) greatly exceeds the number with moderate separation (distances between 2″ and 5″). We are, of course, reasoning from incomplete data, but so far as this affects our argument it favors the opposite conclusion, for it is the exceptionally close pairs and those under 2″ with one component relatively faint which are the ones most likely to have escaped detection. The spectroscopic binaries must also be taken into account and they all belong to the very close pairs. Keeping in mind the proportion of the known spectroscopic binaries to the stars whose radial velocities have been measured, and remembering that this percentage is certain to be increased by the addition of spectroscopic binaries hitherto undetected because of smaller range of radial velocity or longer period, it is safe to say that the double stars (visual and spectroscopic), among the stars to the magnitude of 9.0 inclusive, with distances under 2″ outnumber those with distances between 2″ and 5″ in the proportion of 3 to 1.

This conclusion, based upon data supplied by observation, confirms in the strongest manner the argument from the theory of probabilities that practically all of the closer double stars are binary systems. Certainly we may reasonably assert that a double star with an angular separation of less than 2″ is a binary until the contrary has been demonstrated instead of suspending judgment until definite orbital motion has been observed.

R. G. AITKEN.

MT. HAMILTON, April 29, 1909.

REPORTS OF OBSERVATORIES.[1]

CHAMBERLIN OBSERVATORY, DENVER, COLORADO.

During the year 1908 Mr. SHELTON SWAN and the Director devoted all the time that could be spared from other duties to comet and asteroid observations. Miss MYRTLE RICHMOND, a graduate student in the University of Denver, devoted much time to the reduction of observations, which are now ready for publication.

HERBERT A. HOWE, *Director.*

INTERNATIONAL LATITUDE OBSERVATORY, UKIAH, CALIFORNIA.

Regular observation for the variation of latitude was continued throughout the year 1908. The observing program was that used in 1906 and 1907; assigned by the International Geodetic Association for the period of four years following 1906.0.

The continuity of the work was satisfactory, but was somewhat interrupted in the summer by the heated air and smoke from the most serious brush fires that have visited the immediate vicinity of the observatory since its establishment.

Subsidiary observations and reductions made from time to time indicated uniformly excellent stability of the instrument and constancy of its factors, and entirely satisfactory observational results.

JAMES D. MADDRILL,
Astronomer-in-Charge.

LICK OBSERVATORY, MOUNT HAMILTON, CALIFORNIA.

Inasmuch as the Director's reports to the President of the University of California date from July 1st, the beginning of the academic year, the annual reports appearing in these *Publications* will be for the twelve months beginning with July 1st, save that the series will be inaugurated by a report covering the period January 1, 1908, to July 1, 1909. This report will appear in the number for August.

W. W. CAMPBELL, *Director.*

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[1] Arranged alphabetically according to name.

NAVAL OBSERVATORY, MARE ISLAND, CALIFORNIA.

The work of this observatory during the past year has continued about the same as in former years. The usual number of chronometers has been rated and issued to ships in the naval service and the time service has been maintained as heretofore. By courtesy of the Director of the Lick Observatory, in connection with the co-operation of the Bureau of Equipment, the longitude of the observatory was redetermined in May, 1908, by Professor R. H. TUCKER and Mr. SANFORD from Mount Hamilton. The new seismograph of the Bosch-Omori type, recently purchased, is being mounted in a suitable room, on heavy solid foundations, and it is believed that it will give very satisfactory records of earthquakes. The officer in charge of the observatory has been able to bring to a successful conclusion certain researches on the origin of the solar system, with which he has been occupied for many years. A preliminary report of this work has been printed in the *Publications* of the Astronomical Society of the Pacific, No. 126, and in the *Astronomische Nachrichten,* No. 4308.

T. J. J. SEE,
Professor of Mathematics, U. S. Navy, in Charge.

SOLAR OBSERVATORY, MOUNT WILSON, CALIFORNIA.

The continuation and extension of the researches described in my last annual report have led to the following results:—

(1) The comparative study of the spectra of the limb and center of the Sun favors the conclusion that the relative displacements of the lines near the limb (after eliminating the Doppler effect) are mainly due to pressure. Further laboratory work is required before a final decision can be reached.

(2) The angular velocity of the solar rotation, as determined from the motions of the calcium (H_2) flocculi on the spectroheliograph plates, decreases from the equator toward the poles. The mean velocity at any latitude is very nearly the same as that of the sun-spots.

(3) The angular velocity of the solar rotation, as determined from the motion in the line of sight of the hydrogen represented by dark lines in the solar spectrum, is more rapid at the equator than the angular velocity of the spots and calcium (H_2) flocculi, and decreases less rapidly toward the poles.

(4) The hydrogen ($H\delta$) flocculi, as measured on spectroheliograph plates, move at the equator with about the same angular velocity as the calcium (H_2) flocculi, and show no evidence of retardation toward the poles. This result was obtained before the discovery of solar vortices, and must be tested by measurements of the motions of $H\alpha$ flocculi lying outside of the vortices.

(5) Investigations with an electric furnace have shown that such changes of relative intensity as are exhibited by the lines of iron, titanium, and other substances in sun-spots are produced by lowering the temperature of the furnace. This is in harmony with our conclusion that the temperature of these vapors in sun-spots is lower than in the reversing layer outside of spots.

(6) The flutings of calcium hydride, as observed in another form of electric furnace, have been identified with flutings in our photographs of sun-spot spectra.

(7) Through the use of the $H\alpha$ line of hydrogen, it has become possible to photograph a hitherto unexplored region of the solar atmosphere. The photographs show that sun-spots are surrounded, and perhaps produced, by extensive vortices.

(8) The components of double lines photographed in the spectra of sun-spots with the 30-foot spectrograph of the tower telescope have been found to be circularly polarized in opposite directions. This and much other evidence proves that sun-spots contain a strong magnetic field. By means of spectrographic observations the areas, strengths, and polarities of these fields can be measured, thus permitting a magnetic survey of the entire visible hemisphere of the sun to be made.

In addition to these investigations, much work of research described in other parts of this report has been done, and the work of construction has advanced very satisfactorily. A spectroscopic laboratory in Pasadena, equipped for investigations requiring very high temperatures and pressures, was completed and occupied in March. The 60-inch reflector has been erected.

STAFF.

Mr. W. S. ADAMS has continued his work as superintendent of the computing division, and Mr. G. W. RITCHEY has had charge of construction, both in Pasadena and on Mount Wilson. Dr. ARTHUR S. KING, formerly of the University of California, has been appointed superintendent of the physical laboratory, and commenced work on January 1st. Dr. CHARLES E. ST. JOHN, formerly professor of physics and dean of Oberlin College, joined our staff in May. Mr. FERDINAND ELLERMAN has continued his work with the Snow telescope. Since the completion of the Pasadena laboratory, Dr. OLMSTED has carried on his spectroscopic work there. Miss LOUISE WARE, Miss JENNIE B. LASBY, Miss RUTH E. SMITH, and Miss CORA G. BURWELL have continued their study of photographs in the computing division. Miss LILLIAN M. WICKHAM joined the staff of the computing division on February 1st.

Professor ERNEST F. NICHOLS, Research Associate of the Carnegie Institution of Washington, has been engaged in an investigation of the absorption of the Sun's atmosphere and in laboratory investigations on Mount Wilson during the summer of 1908. Dr. WALTER M. MITCHELL, director of the Haverford College Observatory, and Mr. H. C. PLUMMER, of the Oxford University Observatory, have also spent some time on Mount Wilson, for the purpose of becoming familiar with the investigations in progress.

The work of the Smithsonian Expedition, carried on by Mr. ABBOT during the summers of 1905-06, was renewed on Mount Wilson in May and is still in progress. Mr. ABBOT is assisted in this work by Mr. LOUIS B. ALDRICH, of the University of Wisconsin. It is a satisfaction to state that arrangements have now been made by the Smithsonian Institution to construct a permanent station on the mountain, where studies of the solar constant and other investigations will be continued regularly in the future.

INVESTIGATIONS IN PROGRESS.

Direct Photography of the Sun.—Direct photographs of the Sun have been made daily, as heretofore, with the Snow telescope.

Work with the Spectroheliograph.—The total number of photographs of the Sun taken with the 5-foot spectroheliograph amounted, on September 30th, to 5,196. In March, through the use of plates sensitized for the red by Wallace's process, it became possible to take photographs with the *Hα* line of hydrogen. These were found to differ in important respects from those obtained with *Hδ*. As it soon appeared that the *Hα* images gave a much more complete record of the hydrogen flocculi, mainly because of the great strength of this line in the upper chromosphere and prominences, where *Hδ* is weak, the former line was selected for the daily records, in place of *Hδ*. This change soon led to the discovery that sun-spots are surrounded by vortices, which occur in a region of the solar atmosphere higher than that recorded on *Hδ* plates. A full account of this work, illustrated with photographs of the vortices, may be found in No. 26 of the *Contributions from the Mount Wilson Solar Observatory.*

As the rapid changes in the vortices required that many photographs be made at short intervals, it became necessary to improve the performance of the Snow telescope and to modify the daily program of observations so as to include more *Hα* plates. As the result of experiment it was found that the reduction of the aperture of the cœlostat to 15 inches, while it only partially cured the rapid change of focal length caused by exposure of the mirrors to the Sun, almost completely eliminated such evidences of astigmatism as had seriously injured earlier photographs. For this reason all *Hα* exposures are now made with the 15-inch aperture. The early morning observations are devoted exclusively to the photography of the disk with the *Hα* line. In the late afternoon additional *Hα* plates of the disk are taken, together with one prominence plate (using *Hα* in place of H_2, the line formerly employed), one H_1 disk and one H_2 disk.

The remarkable sharpness of the best *Hα* plates, and the evidence they invariably afford of the existence of definite vortices and currents in the solar atmosphere, have led to many important developments in our work with the spectroheliograph. It now becomes feasible to undertake a systematic examination of sun-spot theories, and to pursue many investigations hitherto out of reach.

Miss Ware's measurements of the motions of 1,680 points in the calcium (H_2) flocculi, made with the heliomicrometer on fifty-one negatives, taken with the 5-foot spectroheliograph during the period June 18th to September 22, 1906, have given the following results for the mean angular rotations (sidereal), corresponding to 5° zones (Table 1). The means in the table combine the results for corresponding latitudes in the northern and southern hemispheres, reduced from synodic to sidereal values.

Miss Ware has also measured the motions of 828 points in the hydrogen flocculi on thirty-five *H*δ plates (Table 1). The difficulties of identification are much greater than in the case of the calcium flocculi, since the hydrogen flocculi change more rapidly in form. It is thus necessary to use plates separated by an interval of only about twelve hours, whereas the same calcium flocculus may frequently be measured on plates separated by an interval of two or three days.

TABLE I.

	Calcium (H_2).		Hydrogen ($H\delta$).	
Zone.	No. of measures.	ξ	No. of measures.	ξ
0° ± 5°	232	14°.5	129	14°.3
± 5 ± 10	262	14 .3	105	14 .1
± 10 ± 15	317	14 .3	145	14 .4
± 15 ± 20	326	14 .2	120	14 .4
± 20 ± 25	259	14 .2	114	14 .5
± 25 ± 30	153	14 .0	95	14 .6
± 30 ± 35	99	13 .8	61	14 .8
± 35 ± 40	26	14 .0	43	14 .8
± 40 ± 45	6	13 .2	16	15 .2

It will be seen that while the motions of the calcium flocculi clearly show a decrease in angular velocity toward the poles of about the same magnitude as in the case of sun-spots, the hydrogen flocculi do not apear to follow the same law.

This work was near completion when the first *H*α photographs of the disk were obtained. The extensive whirls shown on these photographs indicate that the flocculi lying in the neighborhood of sun-spots, or within any region occupied by whirls, are unsuitable for the determination of the solar rotation. The *H*δ plates apparently represent the hydrogen in a lower region of the solar atmosphere, where the whirls are not clearly shown. Nevertheless, the motions of the *H*δ flocculi are probably affected by the whirls, which may account for many peculiarities encountered in the measurement of the plates. It accordingly becomes necessary to study the rotation at the *Hα* level, by means of flocculi which are well outside of the whirls.

A further extension of the spectroheliograph work will soon be possible, as the 30-foot spectroheliograph, constructed in our instrument-shop during the year, is now nearly ready for trial.

Spectra of Sun-Spots.—Many photographs of spot spectra have been made during the year by Mr. ADAMS and myself. Most of these have been taken in the third order of the 30-foot spectrograph of the tower telescope and are greatly superior to the photographs made with the Snow telescope and 18-foot Littrow spectrograph. Double lines, which appear single in the previous photographs, are now clearly resolved, and a great number of additional faint lines, particularly those of flutings, are recorded. The preparation of a catalogue of the lines shown on the earlier plates was well advanced when the first of the new photographs was obtained. Their superiority has made it necessary to prepare a new catalogue, which will contain a much greater number of lines than the former one.

The hypothesis that the relative intensities of sun-spot lines are determined largely by a reduction in the temperature of the metallic vapors below that of the same vapors in the reversing layer is strongly supported by Dr. KING's work with an electric furnace, described on another page of this report. Dr. OLMSTED's detection of the red flutings of calcium hydride in spot spectra affords additional evidence in the same direction.

The discovery of the solar vortices suggested that the rapid revolution of electrically charged particles (assuming a preponderance of positive or negative ions, resulting from diffusion or other cause) should produce a magnetic field within sun-spots (Rowland effect). Photographs of spot spectra taken with the 30-foot spectrograph and the tower telescope showed a great number of close double lines, many of which had previously been seen visually by YOUNG and MITCHELL, who described them as "reversals." I accordingly examined the components of these lines and found their light to be circularly polarized in opposite directions. This is what would be observed if the vapors giving rise to these lines were seen along the lines of force of a strong magnetic field. Other spot lines, which are widened but not doubled, were found to be shifted in position when the nicol was rotated. Spot vortices rotating in opposite directions give doublets having components in which the direction of the circular polarization is reversed. Triplets, the central line of which is plane polarized, also occur in spot spectra. These and similar results, confirmed by many laboratory tests, conclusively prove that a powerful magnetic field (2,800 to 4,500 gausses) exists in sun-spots.

Photographic Comparison of the Spectra of the Center and Limb of the Sun.—The completion of the tower telescope, and the much more powerful spectrographic apparatus available with this instrument, led to the transfer of the spectroscopic work on various parts of the Sun's disk from the Snow telescope to the tower. The considerably greater dispersion available has proved to be of particular value in connection with Mr. ADAMS's study of the spectra of the center and limb of the Sun; the quantities measured being so minute as to require the greatest linear scale which it is possible to obtain. In order to secure the two spectra simultaneously, and thus avoid possible errors arising from change of temperature or unequal illumination of the grating in the two positions of the Sun's image on the slit, a special attachment has been constructed for the purpose. Two small diagonal prisms throw light from the edge of the Sun upon the slit, while the light from the center passes unobstructed on either side of the central prism. Photographs taken with this apparatus have proved extremely satisfactory and thoroughly reliable as regards the absolute displacements involved. At the present time negatives are being taken for the purpose of providing a photographic map of the spectra of these two portions of the Sun's disk, and it is expected that this map will be completed some time during the winter.

In addition to the conclusions drawn from the measurement of the displacements referred to in the last report, the important result has been found that the spark or "enhanced" lines in the spectrum seem to show greater displacements at the limb of the Sun than do the majority of the other lines.

This has a vital bearing on the question of the level at which these lines originate in the Sun's atmosphere. It will require, for satisfactory explanation, a series of laboratory investigations on the displacements of spark lines under pressure.

Spectrographic Investigation of the Solar Rotation.—Mr. ADAMS's photographic investigation of the rotation of the Sun, by means of the displacements of the spectrum lines at the opposite limbs, has been continued throughout the year with the powerful spectrograph of the tower telescope. The advantages of this instrument over the 18-foot spectrograph of the Snow telescope, with which the investigation of 1906 to 1907 was carried on, are very considerable. In addition to the superior quality of the solar image, and greater freedom from astigmatism and change of focus, the larger linear scale furnished by the instrument, and the possibility of setting for different position angles, by rotation about a vertical axis, have proved of great value. The plates employed in the study of the rotation from lines in the violet part of the spectrum have all been taken in the third order of the grating. Plates including the region about $H\alpha$ in the red part of the spectrum have been taken in the second order.

About twenty-five plates covering the same region of the spectrum that was employed in the investigation of last year have been measured and reduced. The degree of accuracy obtained seems to be appreciably higher than that secured with the plates from the 18-foot spectrograph. The comparison of the results of the two series of observations indicates very close agreement in the latitudes running from 0° to 45°. From 60° to the pole, however, the values obtained from the present series fall appreciably below those of last year, the difference amounting to about 0.04^{km} at a maximum. It does not at present seem probable that this difference is to be ascribed to a real variation in the rotation of the Sun, since it is not shared in by the zones of lower latitude, in which the activity of the Sun, as indicated by the presence of spots and flocculi, is much greater. A more probable explanation would seem to be that it is due to errors arising in the former series of observations, from astigmatism and other defects of the solar image. The values obtained from the present year's series of observations are now being collected and will be published within a short time.

One of the most important contributions furnished by the investigation of the rotation of the Sun is Mr. ADAMS's discovery that the hydrogen gas producing the α line of hydrogen moves with a decidedly greater angular velocity than the general reversing layer, and seems to be subject to quite a different law from that of the ordinary equatorial acceleration. The first indications that a result of this kind was to be expected were furnished by the study of photographs of the spectra of the center and limb of the Sun, and as soon as these became evident the investigation was continued with the regular rotation apparatus of the tower telescope. The results obtained from the earlier plates of the series are given in Table 2:—

TABLE 2.

	v km	$v+v_1$ km	ξ	Period days
—0°.1	2.07	2.21	15°.7	22.9
9 .3	2.01	2.15	15 .5	23.2
14 .8	1.96	2.10	15 .4	23.4
22 .7	1.90	2.03	15 .6	23.1
29 .7	1.73	1.87	15 .3	23.5
44 .5	1.44	1.55	15 .4	23.4
59 .3	1.04	1.12	15 .6	23.1
73 .5	0.63	0.67	16 .7	21.6

The inclusion of a larger number of results will probably indicate a slight decrease in the value of the angular velocity toward the pole of the Sun, but the law will evidently be very different from that of the reversing layer. It also seems probable that the value of the angular velocity at the equator will be somewhat reduced when a larger series of observations is available.

Some recent work on the blue line of calcium at λ 4227 indicates that the rate of rotation given by this line differs from that of the general reversing layer. A series of photographs obtained especially for the study of this line is now being investigated.

Absorption and Scattering in the Solar Atmosphere.—Professor E. F. NICHOLS, Professor of Physics in Columbia University and Research Associate of the Carnegie Institution of Washington, has just completed an important investigation on Mount Wilson. The object of the work is to determine the law of absorption and scattering of light in the solar atmosphere. An image of the Sun, formed by the Snow telescope, falls upon a slit. The rays which enter the slit are rendered parallel by a collimating mirror, pass through a large prism, and the spectrum thus formed is brought to a focus by a second mirror. A bolometer, kindly supplied by Mr. ABBOT, is set at a certain wave-length. As the sun's image transits across the slit, the deflections of the galvanometer are recorded on a moving photographic plate. In this way photographed curves, corresponding to a number of different wave-lengths, give a measure of the solar radiation at points along a diameter parallel to the direction of the diurnal motion. Several refinements of the method, which are due to Professor Nichols, should lead to results of high precision. The observations have been completed and will be reduced as soon as possible.

PHYSICAL LABORATORY.

To meet the needs of experimental work, which require the use of electric currents much stronger than can be economically generated on Mount Wilson, the construction of a new physical laboratory, on land adjoining our Pasadena instrument-shop, was begun in the autumn of 1907. On January 1, 1908, the work had progressed as far as the completion of the exterior walls and roof and the excavation of the 30-foot pit in the middle of the floor. During January and February the interior arrangements were for the most part completed, including the cementing and drying of the pit, the laying of the cement floor with conduits for electric wires embedded in the cement, the construction of concrete piers for the apparatus, the installation of the electrical machinery, and the fitting up of the chemical laboratory and dark-room. About March 1st actual investigation work began with the mounting of the 30-foot spectrograph in the pit and the setting up of the large electric furnace, the construction of which had been completed in the machine shop after being received from the maker. A description of the laboratory may be found in *Contributions from the Mount Wilson Solar Observatory,* No. 27.

The electric furnace quickly yielded results which demonstrated its superiority for spectroscopic work over any existing apparatus of the kind. The work so far carried on by Dr. KING has included a study of the spectra of iron, chromium, titanium, and vanadium, as given by the furnace in vacuum at different temperatures. The effect of temperature and different amounts of vapor upon the principal lines of calcium was also observed. A series of measurements were made with an optical pyrometer to obtain the temperatures at which the various spectra were produced. Temperatures as high as 3,000° C. were measured. The spectra show almost as many lines as are given by the electric arc; while the effects of different temperatures in changing the relative intensity of lines are of high interest when considered in connection with both astronomical and physical problems. The effect of different gases in the furnace, also of high pressures and the observation of absorption phenomena, offer each a large field of work which has not yet been taken up.

During April an electric furnace of the Moissan type, inclosed in an air-tight chamber, was set up and has been used by Dr. OLMSTED for the investigation of the spectra of hydrides, to be used for comparison with solar spectra in the identification of unknown lines, especially of the flutings obtained in the spectra of sun-spots. Good results for the spectra of magnesium and calcium hydrides are being obtained.

The recent discovery of the separation of lines in sun-spots, indicating the presence of magnetic fields on the Sun, has led to a supplementary laboratory investigation of the Zeeman effect, the large Du Bois electro-magnet being arranged so that an electric spark between the poles may be photographed either parallel to the lines of magnetic force or at an angle to them. The magnet gives a field strength up to 36,000 c. g. s. units. Photographs are being obtained of the spectra of iron and other substances, giving an excellent separation of the spectrum lines for magnetic fields of known strength, allowing a detailed comparison with the separations obtained in the solar photographs.

Most of the laboratory investigations cover the whole range of the visible spectrum, requiring the use of photographic plates sensitive to red light in addition to those commercially obtainable. The laboratory dark-room is fitted up for the sensitizing of plates for the red region, which are thus used while perfectly fresh and are handled with the same facility as the ordinary plates.

The comparison of intensities of lines on photographic plates has been carried on by Miss WICKHAM of the computing division through the use of the Zeiss spectrocomparator, adapted so as to show a portion of the spectrum under examination and a specially prepared photographic scale in the field of view at the same time, giving a definite value to the intensity of each spectrum line and allowing an accurate comparison of the intensities of lines in different spectra.

COMPUTING DIVISION.

Some of the results obtained in the computing division, under the direction of Mr. ADAMS, have already been given. The heliomicrometer has been used by Miss WARE for all measurements of the positions of flocculi. The rapidity of measurement has been greatly increased by ruling one hemisphere of the globe with meridians and parallels 1° apart. The position of the cross-hairs, after they have been set on a flocculus, is estimated to tenths of a degree. The precision of measurement proves to be amply sufficient; in fact, the latitudes and longitudes are almost as precise as those obtained with the aid of the circles.

The measurement of the areas covered by the calcium flocculi, to serve as an index of the solar activity, has been continued throughout the year. This work has been carried on by Miss SMITH with the aid of the special photometer devised for this purpose and referred to in the report of last year. The method of reduction which has been followed is the same as that previously described and the results obtained have proved to be fully as satisfactory as the character of the objects measured would seem to warrant. The values obtained for a period of about seven months have been platted and indicate very clearly the variation in the areas covered by the flocculi as the spot-groups pass across the surface of the Sun. The time interval is of course too short to give any indication of the eleven-year period, but there is every reason to suppose that these determinations will furnish an excellent measure of the Sun's activity.

The measurement of the plates used in the determination of the rotation of the Sun has been done for the most part by Miss LASBY, and in addition she has devoted considerable time to the measurement of the displacements found in the spectra of the center and limb of the Sun. The extension of the rotation work to include the lines of hydrogen and the line of calcium at λ 4227 has increased considerably the amount of measurement which it has been necessary to do in carrying out this research.

The definitive reduction of our plates of the sun-spot spectrum, and the identification of the unknown lines which appear on them, has involved a great amount of measurement and reduction. This work has been carried on for the most part by Miss BURWELL and Miss WICKHAM. Miss BURWELL has determined the wave-lengths of the sun-spot lines, and Miss WICKHAM has measured, for purposes of identification, plates of the titanium-oxide flutings obtained in the laboratory. Some idea of the amount of labor involved may be obtained from the fact that in the extent of spectrum between λ 5000 and λ 5500 there occur over 1,500 lines, whose wave-lengths in the spot spectrum must be determined and for which suitable identifications with laboratory spectra have to be found.

In addition to her work on the measurement of the titanium-oxide flutings, Miss WICKHAM has devoted much time to the estimation of the intensities of the lines upon the plates of furnace spectra obtained by Dr. KING.

CONSTRUCTION DIVISION.

The construction division, under the superintendence of Professor RITCHEY, has been occupied during the year with the erection on Mount Wilson of the steel building and dome for the 60-inch reflector; the completion of this instrument, its transportation to the mountain and its erection in the dome; the erection and equipment of the new spectroscopic laboratory in Pasadena; the construction of a spectroheliograph of thirty feet focal length and a grinding-machine for the 100-inch Hooker mirror; the completion of the Mount Wilson road; and other miscellaneous work.

The instrument and optical shops were closely occupied with the 60-inch reflector during the entire year. The optical work included the grinding and figuring of the two plane and two hyperboloidal mirrors, which were tested in combination with the 60-inch mirror. In the instrument shop the mounting was completed and erected, so that the operation of all parts of the mechanism could be thoroughly tested before they were sent to the mountain. In the tests the various quick and slow motions, effected by electric motors, worked perfectly, and the mounting showed no evidence of flexure.

The experience of the previous year had shown the necessity of widening some sections of the Mount Wilson road, in order to permit the large and heavy parts of the mounting to be carried safely on the automobile truck. This work was done in the spring, immediately after the close of the rainy season. At the same time the erection of the steel building and dome was resumed. During June and July the mounting was taken to the summit without difficulty on the truck, though four strong mules were needed to assist the engine in hauling the heaviest loads, weighing five tons, over the steep grades. The most troublesome load was the large steel telescope-tube, 6.5 feet in diameter and 18 feet long, which was taken up as a single piece. All parts of the telescope, including the 60-inch mirror, reached the summit without the slightest injury. Work on the dome and building was completed early in September, and the telescope was ready for use in December. It is now yielding excellent photographs of nebulæ and other objects.

A spectroheliograph of thirty feet focal length, designed for use with the tower telescope, has been completed and is now in use. The great linear dispersion of this instrument, and the fact that it will permit three photographs of the same region of the Sun to be taken simultaneously with the light of three different lines, should prove advantageous in certain new fields of solar research. The dispersing member of this spectroheliograph is a large fluid prism, with circular faces twelve inches in diameter, which is twice traversed by the light (Littrow arrangement).

A 100-inch disk for the Hooker telescope mirror has been received from the St. Gobain plate-glass works, but it is not sufficiently homogeneous, and another one will be cast.

George E. Hale, *Director.*

STUDENTS' OBSERVATORY, BERKELEY ASTRONOMICAL DEPARTMENT, UNIVERSITY OF CALIFORNIA.

The work of the Berkeley Astronomical Department during the last year has been confined almost entirely to instruction. The enrollment for the year exceeds the five hundred mark. No additions have been made to the teaching force. Several courses that are usually given could not be given this year, due to the absence of the Director, Professor A. O. LEUSCHNER, who has been abroad since July on his sabbatical leave. Because of his absence no work has been done upon the Watson asteroids.

A short but excellent series of photographs of Comet Morehouse was obtained in October by Mr. MEYER. The orbit of this comet was computed by Messrs. EINARSSON and MEYER.

The Acting Director, assisted by Mr. MEYER, computed the orbit of *Jupiter's* VIII Satellite by LEUSCHNER's method.

A few micrometer observations of Comet Morehouse have been made. The regular seismological and meteorological observations have been continued during the year. The orbits of Comet Morehouse and *Jupiter's* VIII Satellite have been published in the *Lick Observatory Bulletin.*

A few additions have been made to the equipment of the observatory, among which are: 1. A new position micrometer for the 6-inch telescope, made by GAERTNER of Chicago (the old micrometer has been adapted for use on the 5-inch telescope; 2. A small spectrometer for student use; 3. An induction coil; 4. A storage battery.

In September Director LEUSCHNER attended the Versammlung der Astronomischen Gesellschaft at Vienna, when he presented an outline of his new analytical method for determining the orbits of new satellites. His paper is entitled "Versuch einer Bahnbestimmung mit sofortiger Berücksichtigung der Störungen." It has been published in the *Vierteljahrsschrift der Astronomischen Gesellschaft.*

R. T. CRAWFORD, *Acting Director.*

GENERAL NOTES.

A Bright Meteor.—Dr. G. K. GILBERT, of the U. S. Geological Survey, has sent a memorandum of a bright meteor seen by him at 9:40 P. M. on April 4, 1909, at Berkeley, California. From a sketch furnished by the observer it is shown that the meteor appeared some ten degrees below *Alioth* (*ε Ursæ Majoris*), moved downward and toward the west, disappearing behind the Berkeley hills some distance west of Grizzly Peak, at a point which would make nearly an equilateral triangle with *Alioth* and *Polaris.* This point was probably very close to the head of the *Dragon.* Dr. GILBERT'S notes concerning the meteor are as follows: "Seen from campus, near athletic field, Berkeley, California. Motion slow. Meteor increased in brilliancy as it descended and also divided so as to make a cluster. Train distinct but much less persistent than those of the *Perseids.* Train yellower than the meteor. Diameter of cluster before disappearing behind hills about one tenth of Moon. A meteor as bright as *Venus* was seen the previous evening."

Compendium of Variable Stars.—At the last meeting of the Astronomische Gesellschaft Rev. Father J. G .HAGEN, S. J., announced the preparation, in collaboration with Dr. STEIN, of a book on variable stars, under the title, "Ein Lehrbuch der veränderlichen Sterne." The book is to consist of two parts, a technical part to be prepared by Mr. HAGEN and a theoretical part to be prepared by Mr. STEIN.

The technical part is to be treated under three heads—statistics, methods of observing, and methods of reduction,—and each of these is to be treated under several sub-heads. The theoretical part is to be devoted to the several theories which have been advanced to explain the phenomena of variable stars. These are to be treated under two general heads—first, those referring to single stars, and, second, those referring to double or multiple stars.

The above information is taken from a rather elaborate outline of the contents of the proposed book given in the *Vierteljahrsschrift der Astronomischen Gesellschaft,* **43,** part 4. This book will, we feel sure, be of great interest to variable star workers, and the reputations of the authors guarantee that the work will be executed with great care and scientific accuracy.

S. D. T.

Notes from "Science."—Professor H. G. van de Sande Bakhuyzen has retired from the directorship of the Leyden Observatory and is succeeded by Mr. E. F. van de Sande Bakhuyzen.

Dr. Max Wolf has been appointed director of the observatory at Heidelberg in succession to Dr. Wilhelm Valentiner, who has retired owing to ill health.

Dr. Hermann Kobold has been called from Kiel, to a professorship of astronomy at Berlin.

Professor George E. Hale, director of the Mount Wilson Solar Observatory, has been elected a foreign member of the Royal Society.

A geodetic survey department for Canada has been established under Dr. W. F. King, chief astronomer of the Dominion.

National Academy.—At the annual meeting of the National Academy of Sciences held in Washington during the latter part of April two papers upon astronomical subjects were presented: "The Nature and Possible Origin of the Milky Way," by G. C. Comstock; and "Determinations of Stellar Parallax from Photographs Made by Arthur R. Hinks and the Writer," by H. N. Russel (introduced by G. C. Comstock). An abstract of Professor Comstock's paper has been printed in the number of *Science* issued on May 21st.

Four California astronomers took part in the Astrographic Chart Conference at Paris, April 19th,—Professors Hale, Leuschner, Perrine, and Ritchey.

There is an interesting article in the May number of *Observatory*, by Professor Whittaker, Astronomer Royal of Ireland, on "The Professional Training of Astronomers." The article was intended to be suggestive to university students of astronomy and their teachers, but will also interest amateurs who desire to equip themselves for astronomical study. The periodical is in the Society library.

NEW PUBLICATIONS.

ALLESIO, ALBERTO. Determinazione della gravita relativa fra Padova e Potsdam. Genova. 1908. 4to. 148 pp. Paper.

Annalen der Kaiserlichen Universitäts-Sternwarte in Strassburg. Beobachtungen von Nebelflecken und Trabanten. Karlsruhe. 1909. Folio. 385 pp. Paper.

Annual report of the director Kodaikánal and Madras observatories for 1908. Madras. 1909. Folio. 26 pp. Paper.

BLOCK, HENRIK. Sur les chocs dans le problème des trois corps. Uppsala and Stockholm. 1908. 8to. 32 pp. Paper.

BOCCARDI, GIOVANNI. Osservazioni di ascensioni sette eseguite nel R. Osservatorio di Torino negli anni 1904-06. Torino. 1908. Folio. 118 pp. Paper.

CHARLIER, C. V. L. Das Planetarische Rotationsproblem. Uppsala und Stockholm. 1908. 8to. 14 pp. Paper.

LEON, LUIS G. Observaciones solares. Mexico. 1909. Folio. Paper.

Durante el mes de diciembre de 1908. 4 pp.
Durante el mes de enero de 1909. 5 pp.

MACMILLAN, WILLIAM D. On the loss of energy by friction of the tides. Extracted from Publication 107 of the Carnegie Institution of Washington, pp. 69-75. 8to. 67 pp. Paper.

Mitteilungen der Grossh. Sternwarte zu Heidelberg. XIV. Der persönlicher Fehler bei der Beobachtung von Sternbedeckungen. Von E. PRZYBYLLOK. Karlsruhe. 1909. 8to. 27 pp. Paper.

MOULTON, FOREST RAY. On certain relations among the possible changes in the motions of mutually attracting spheres when disturbed by tidal interactions and notes on the possibility of fission of a contracting rotating fluid mass. Extracted from Publication 107 of the Carnegie Institution of Washington, pp. 77-133 and 135-160. 4to. 25 pp. Paper.

Results of observations made at the Coast and Geodetic Survey magnetic observatories. DANIEL L. HAZARD. Washington. 1909. Folio. Paper.

At Baldwin, Kansas, 1901-1904. 138 pp.
At Chentenham, Maryland, 1901-1904. 206 pp.
At Vieques, Porto Rico, 1903-1904. 70 pp.
At Sitka, Alaska, 1902-1904. 129 pp.
Near Honolulu, Hawaii, 1902-1904. 130 pp.

SCHIAPARELLI, GIOVANNI. Orbite cometarie, correnti cosmiche, meteoriti. Estratta dalla Rivista di Fisica, Matematica e Scienze Naturali (Pavia). Pavia. 1908. 8to. 27 pp. Paper.

SMILLIE, THOMAS W. Recent progress in color photography. From the Smithsonian report for 1907, pp. 231-237. Washington. 1908. 8to. 6 pp. Paper.

Veröffentlichungen der Grossh. Sternwarte zu Heidelberg. Mikrometrische Messungen von Doppelsternen. Von E. PRZYBYLLOK. Karlsruhe. 1908. 4to. 91 pp. Paper.

Verslag van den Staat der Stenewacht te Leiden en van de Aldaar volbrachte Waaremingen, van 18 September 1906 tof 21 September 1908. H. G. VAN DE SANDE BAKHUYZEN. Leiden. 1909. 8to. 31 pp. Paper.

WILLIAMS, A. STANLEY. Zenographical fragments II. The motions and changes of the markings on *Jupiter* in 1888. London. 1909. 8to. 104 pp. Paper.

ZAPP, ERNST. Untersuchung eines speziellen Falles des Drei— und Vierkörperproblems. Inaugural-dissertation. München. 1908. 84 pp. Paper.

AMENDMENT TO BY-LAWS.

At the annual meeting of the Board of Directors of the Astronomical Society of the Pacific, held in San Francisco on March 27, 1909, a report was presented by the Committee on Publication recommending an amendment to the By-Laws as follows:—

> We recommend that the second paragraph of article IX of the By-Laws be amended to read as follows:—
>
> "A meeting shall be held in the Library of the Lick Observatory at a suitable hour on the last Saturday of August; and meetings shall be held in the rooms of the Society, in San Francisco, at eight o'clock P. M. on the last Saturdays of January, March, June and November, but it shall be within the discretion of the President to designate other places of meeting, in San Francisco or vicinity, for the meetings of January, June and November, whenever, in his opinion, such change will be to the advantage of the Society."

It was the unanimous opinion of the six Directors present—viz., Messrs. BURCKHALTER, HALE, GALLOWAY, CUSHING, MOLERA, and CRAWFORD—that the By-Laws should be amended as recommended by the committee, and the Secretary was instructed to obtain the written consent of at least three other Directors, which has now been done through Directors CAMPBELL, AITKEN, and RICHARDSON.

D. S. RICHARDSON, *Secretary.*

OFFICERS OF THE SOCIETY.

Mr. W. W. Campbell	*President*
Mr. G. E. Hale	*First Vice-President*
Mr. F. Morse	*Second Vice-President*
Mr. E. J. Molera	*Third Vice-President*
Mr. D. S. Richardson	*Secretary and Treasurer*
Mr. R. G. Aitken (Mount Hamilton, Cal.)	*Secretary*

Board of Directors—Messrs. Aitken, Burckhalter, Campbell, Crawford, Crocker, Cushing, Galloway, Hale, Molera, Richardson.

Finance Committee—Messrs. Molera, Crocker, Cushing.

Committee on Publication—Messrs. Townley, Maddrill, Curtis.

Library Committee—Messrs. Crawford, Townley, Einarsson.

Comet-Medal Committee—Messrs. Campbell (ex-officio), Townley, Curtis.

NOTICE.

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January of each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary at Berkeley ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, S. D. Townley, Stanford University, California.

The Secretary at Berkeley will send to any member of the Society suitable stationery, stamped with the seal of the Society, at cost price as follows: a block of letter paper, 40 cents; of note paper, 25 cents; a package of envelopes, 25 cents. These prices include postage.

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, and November, and at the Lick Observatory on the last Saturdays of June and August. Members who propose to attend the meetings at Mount Hamilton should communicate with the Secretary at Berkeley, in order that arrangements may be made for transportation.

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PUBLICATIONS

OF THE

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OF THE PACIFIC.

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SIMON NEWCOMB.

PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

VOL. XXI. SAN FRANCISCO, CALIFORNIA, OCTOBER 10, 1909. No. 128

SIMON NEWCOMB.

BY R. G. AITKEN.

That by the death of SIMON NEWCOMB on the 11th of July, 1909, America lost her foremost astronomer, if not her foremost man of science, is universally acknowledged. We may, indeed, say with confidence that Professor NEWCOMB, for the past thirty years, ranked as one of the two or three greatest astronomers, not only of America, but of the world. It is a matter of satisfaction to recall that our Society brought this fact into prominence more than ten years ago.

In the autumn of 1897 letters were addressed by our secretary to the directors of the Berlin, Greenwich, and Paris observatories in Europe, and of the Harvard, Lick, and Yerkes observatories in this country, asking them to assist us in carrying out the statutes for the award of the Bruce Medal by nominating not more than three persons each who, in their judgment, were entitled to receive the medal[1] "for distinguished services to astronomy."

The statutes for the award of this medal, wisely adopted by Miss BRUCE at Professor HOLDEN'S suggestion, provide that the medal can be awarded by the Directors of our Society only to persons thus nominated by the heads of six of the great observatories of the world, and I think I am betraying no confidence when I say that the Directors of the Society, so far, have conferred the medal upon that astronomer whose name was most prominent on these nominating lists.

Therefore, as Mr. WILLIAM ALVORD, President of the Society, in his address on awarding the first Bruce Medal, said, " . . . it will be perfectly clear that the recipient must have endeared himself, in a scientific sense, to the astronomers of the world." I cannot do better than to quote further from this address: "Not only will this also be true of each subsequent bestowal of the medal, but such a condition must especially mark this first presentation, since, according to the desires of Miss BRUCE, the medal is to be 'international in character, and may be awarded to citizens of any country and to persons of either sex.' It must strike us, then, with peculiar force that of all the names of living astronomers that have been so brilliantly connected with the wonderful advances in astronomical research during the past half-century, with all the manifold branches of observational work, mathematical investigation, spectroscopic and photographic study, in which to seek out a worthy exponent for this distinction, one name stood forward so prominently in the communications from heads of six leading observatories of the world, that the Directors of this Society could but set the seal of their approval upon the verdict of his peers, and award the first Bruce Medal to SIMON NEWCOMB."

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[1] For the year 1898, the first award.

It is not my purpose to write a formal sketch of Professor NEWCOMB's life. The salient features of his career may be gathered from any one of the numerous notices that have been printed since his death, or from the address[1] from which I have just quoted. And any readers who desire a more complete account than these articles provide cannot do better than to read his "Reminiscences of an Astronomer," in which he has given us not only an excellent autobiography but also many interesting sidelights on the history of astronomy in this country.

I do, however, desire to dwell upon certain features of his career that seem to me worthy to be strongly emphasized, particularly the great services he rendered to astronomy outside of his technical contributions and researches, and, in this connection, to bring again to your attention the important relation in which he stood to the Lick Observatory in its early history.

It was in the summer of 1874 that Mr. D. O. MILLS, President of the first Board of Lick Trustees, visited Washington to consult with the astronomers there, especially Professor NEWCOMB, concerning the proposed Lick telescope. As always in such matters, NEWCOMB took the greatest interest in this new foundation, and gave the best advice in his power. Among other things, he suggested at that time that Professor HOLDEN would be well qualified to serve as director, and we have the authority of both men for saying that sketches of the plans of the observatory were drawn by them in that year. The plans finally adopted did not differ in material points from these early sketches.

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[1] See these *Publications*, **10**, 49, 1898.

In 1875, Professor NEWCOMB visited Europe for the Lick trustees "with a view of determining whether there was any chance of getting the telescope made abroad."

The report was not very encouraging, and when Mr. LICK'S death left the third Board of Trustees free to act as they deemed best, the contract for the lenses was awarded, as is known, to the CLARKS. It is certain that NEWCOMB strongly favored this, and also that his advice weighed heavily in the decision to build a refracting telescope rather than a reflector. In 1876 Captain FLOYD, chairman of the third Board of Trustees, visited him; in 1879 FLOYD and FRASER, superintendent of construction of the observatory, consulted him in Washington; in September of that year he spent several days on Mount Hamilton, while BURNHAM was engaged, at the recommendation of both NEWCOMB and HOLDEN, in testing the atmospheric conditions there. It was in the autumn of the same year that the preliminary plans for the building were drawn at Washington under the joint direction of these two astronomers in NEWCOMB'S office. In 1885 he was again consulted, this time "on the question of choosing Professor HOLDEN as president of the University" of California; and in 1887 he was invited to go with Captain FLOYD to Cleveland "to inspect the telescope, which was now nearly ready for delivery."

I think it is clear from these facts that Professor NEWCOMB'S advice and recommendations were most potent factors in shaping the policy of the Lick Trustees, not only in the matter of buildings and equipment, but in the far more important matter of selecting the man who was to plan and direct the scientific work of the new observatory. To the close of his life Professor NEWCOMB continued to take the keenest interest in the work of the Lick Observatory, and stood ready at all times to aid its successive directors in every way in his power.

This little history furnishes an excellent example of what I mean by the influence Professor NEWCOMB exerted upon the progress of astronomy in this country during the half-century of his active career.

His official position, his eminence as an investigator, his practicality and sound common sense, and his forceful personality combined to give to all of his opinions the greatest weight. He was of course very influential in securing the powerful equipment of the Naval Observatory, and he was one of the chief advisers to the National Government in the development of several of the scientific bureaus at Washington. It is well known, also, that he was freely consulted by the astronomers of this country not only, but by those of Europe as well, on many of the important projects that have advanced our science during his lifetime.

Now we find him one of the leading members of the international committee which, at Paris in 1896, adopted a uniform system of constants for use in the nautical almanacs and ephemerides of the world; again, as leader of the astronomical congress held in connection with the dedication of the Yerkes Observatory; then as first president (re-elected as long as he would serve) of the Astronomical and Astrophysical Society of America; as president of the International Congress of Arts and Sciences at St. Louis in 1904;—the list could be made almost as long as the list of his scientific memoirs or as that of the honorary degrees, medals, and other distinctions conferred upon him. In all of these capacities his qualities of leadership were strongly exerted to stimulate the broadest possible development of the science to which he was devoted and particularly to encourage the growth of that spirit of co-operation in large programs of work that now characterizes astronomy.

Nor was he less interested in promoting the work of individual astronomers of whose ability he was convinced, a fact to which several of the recently published notices of his life bear witness.

While thus doing what he could to advance the science of astronomy professionally, Professor NEWCOMB also realized the desirability of popularizing, in the best sense of the word, the advances of our knowledge of the universe. Too often it happens that the scientific investigator considers it beneath his dignity to write a popular article. In many other cases the able student is not qualified to present the results of his work in non-technical language. But NEWCOMB added to the power of clear thinking the faculty of lucid expression, and he cheerfully devoted these powers to the task of writing books and magazine articles in which the latest results of astronomical research were made clearly intelligible and even fascinating to the general reader. Through these writings and his numerous lectures and addresses he exerted an influence on the progress of astronomy that is incalculable. When one considers the enormous amount of labor involved in the extensive technical investigations which he conducted, one must wonder how he found time for all of these additional activities. It is obvious that he could only do so because, in addition to his genius as a mathematician and astronomer, he possessed in an unusual degree the power of continuous work.

As a general rule a man who would carry a great piece of research work to completion must take as his motto, "This one thing I do," and must decline to undertake any other serious duties. So far as his professional labors were concerned, Professor NEWCOMB, too, adopted this motto, at least in spirit, for he steadfastly refused to be turned away from the life task he had chosen by any offer, however tempting, of work in other lines.

It is not necessary at this time to review this great work, which amounted practically to a complete revision and rediscussion of all the data of gravitational astronomy. It has been dealt with in part in the Bruce Medal address, already quoted, and more fully in a recent article in *Science*[1] by Dr. G. W. HILL, who was Professor NEWCOMB's associate in a considerable part of it, and who of all living men is perhaps best fitted to estimate its importance.

It is a pleasure to think that Professor NEWCOMB had the satisfaction of rounding out his work by the completion of his final memoir on the Moon's motion. His unfaltering loyalty and indomitable will and courage kept him at his work to the closing hours of his life, and only a few weeks before the end came the final pages were written.

---

[1] *Science*, **30**, 353, (Sept. 17, 1909).

It is gratifying, too, to think that, so far at least as the scientific world is concerned, his great services were adequately recognized and honored during his lifetime.

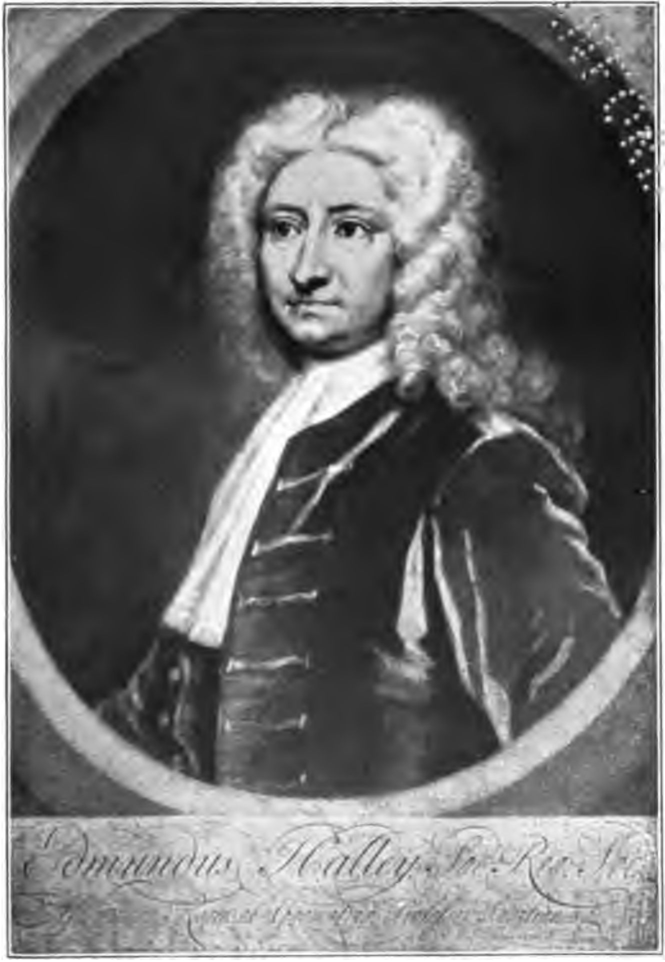
September, 1909.

THE RETURN OF HALLEY'S COMET.

By W. W. Campbell.

A celestial event of unusual interest is expected soon—the return of Halley's Comet. Its appearance will be welcomed as the coming of a faithful friend, whose visits to the Sun's domains have repeated themselves once every seventy-seven years since long before the time of Christ. Any day may bring the news that this object has been re-discovered, near the northern edge of the constellation *Orion;* but we are really not expecting the announcement until the last third of 1909. The comet will be faint when first seen, for we know quite closely where to look, and the most powerful photographic telescopes in several countries are periodically "prospecting" the critical region.

Why is this comet known as Halley's? The incidents connected with its christening form an interesting chapter in the early history of astronomy. A brilliant comet appeared in 1682, when Halley was a young man, in England. This was Halley's Comet, but his name was not connected with it until much later, as we shall explain. Halley's friend, the great Sir Isaac Newton, had but recently (about 1670-80) discovered the law of gravitation, and had proved that a comet or other body completely subject to the Sun's attraction must move in an ellipse around the Sun. Newton was of a retiring disposition and took no steps to make known his immortal discoveries. Halley, on the contrary, was a man of action. These characteristics of the two men are apparent from their portraits. The manuscript copy of Newton's *Principia* was entrusted to Halley, and the latter, in the absence of other funds available for the purpose, published the book in 1686, at his own expense, though he was a man of small financial


Edmundus Halley Soc. Reg. S.

EDMUND HALLEY.

means. This act alone stamps HALLEY as worthy of our homage.

HALLEY realized the wonderful import of The Great Law, certainly as early as 1685, but his opportunity for systematic work in astronomy did not come until 1704, when he was appointed professor of geometry at Oxford. He immediately began the study of comets, basing his studies upon NEWTON'S law. He became the first great calculator of comet orbits. In a little more than a year he had twenty-four to his credit; orbits of all the comets, in fact, for which he could find accurate observations. This meant prodigious labor, in those days, for the good observations and the highly developed methods of our time were unknown. He found that three comets out of the twenty-four had traveled from distant space, around the Sun, and out into distant space, *along the same path,* whereas the other twenty-one had each a different path. Were these three comets one and the same body? If so, their common orbit must be an ellipse. The crude observations of the sixteenth and seventeenth centuries did not permit him to decide whether the orbit was a long ellipse or a parabola (a curve extending out to an infinitely great distance). If the latter, the three comets would have traveled away from our solar system never to return. If they were the same body, they should have returned at about equal intervals of time; and this is what did occur, for the dates when the three comets had been nearest to the Sun were—

1531	August 24	Interval, 76.2 years
1607	October 16	Interval, 74.9 years
1682	September 4	

The small inequality of intervals he correctly attributed to the disturbing attractions of the planets *Jupiter and Saturn.* He predicted that the great comet would complete another revolution in its orbit in seventy-five or seventy-six years and reappear about 1758. He said that he could not predict the time more accurately, for the effects of *Jupiter's* and *Saturn's* disturbing attractions were not yet computed. HALLEY (born 1656, died 1742) knew that he would not live to witness the return, but he confidently and patriotically called upon posterity to remember that this prediction had been made by an Englishman,—*"ab homine Anglo."*

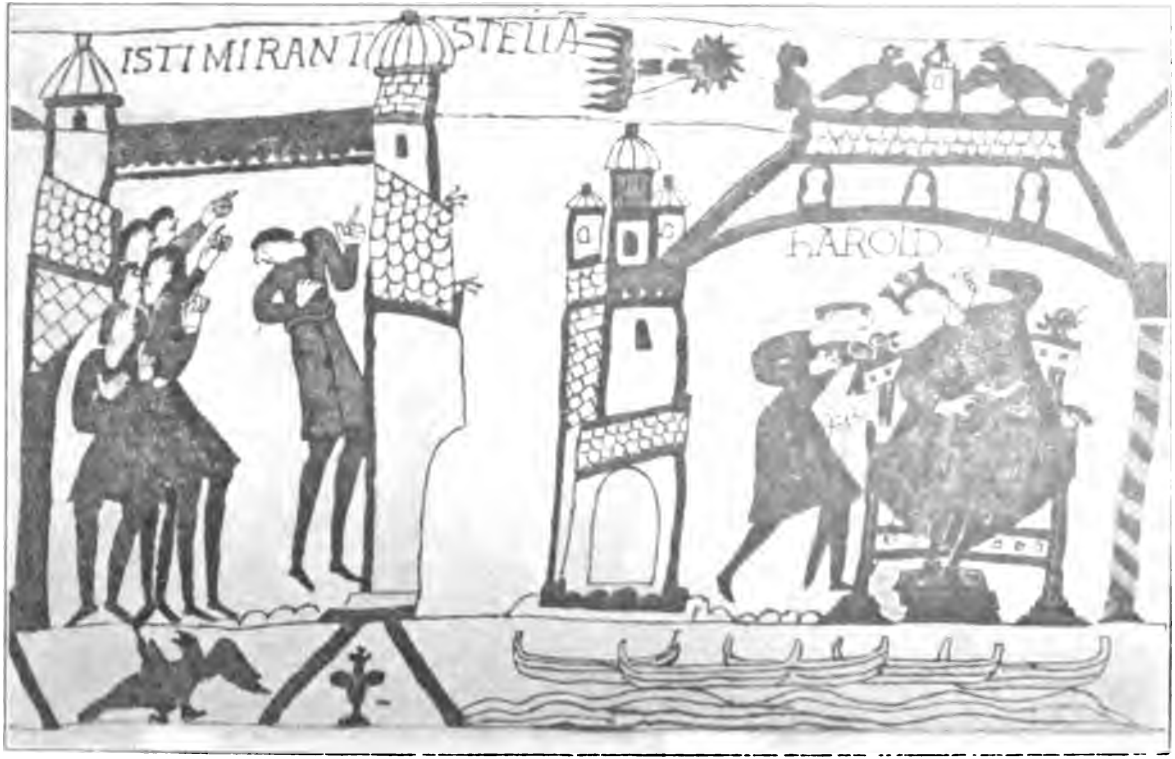
The comet did return, in March, 1759. It was a little later than expected because of the disturbing attractions of the planets *Uranus* and *Neptune,* which had not yet been discovered, and whose influence upon the comet's orbit, therefore, could not be taken into account. This was indeed a great triumph in exact science, made possible by NEWTON'S overwhelming genius and HALLEY'S vigor. It is easy to predict the returns of comets in the twentieth century, but this is so because NEWTON and HALLEY lived and labored as pioneers.

Halley's Comet reappeared in 1835, within a few days of the predicted time. It is due to be again "in perihelion," *i. e.*, nearest to the Sun, in the first half of April, 1910. The comet, though invisible, is at present (April, 1909) much closer to us than *Jupiter* is, and slowly drawing nearer to the Sun. When we may expect to see it without telescopic assistance and how bright it will be at maximum are too uncertain for prediction. Certainly for a few months in the first half of 1910 it should be a conspicuous object. Comets brighten and develop their tails as they approach the Sun, reaching their greatest development when in or near perihelion. For this reason it is their unfortunate practice to disappear from view, in the Sun's glare, just when they are largest; and Halley's Comet will be out of sight for a few days while it is passing on the other side of the Sun, probably in March, 1910. We should see it at its best just after perihelion passage.

The history of this most famous of comets prior to HALLEY'S first date, 1531, has been traced by three able English astronomers, HIND, COWELL, and CROMMELIN, as far back as B. C. 240. In all, twenty-nine appearances recorded in history have been identified. These have occurred at average intervals of seventy-six and three-quarters years. The individual values of the intervals have varied between seventy-four and a half and seventy-nine years, according as the disturbing actions of the planets combined to shorten or to lengthen the period.

There are extant several quaint pictorial representations at many of its early returns. An especially interesting one, though of minimum scientific value, is for the return in 1066,—the year of William the Conqueror's invasion,—as preserved in the famous Bayeux Tapestry. Sir JOHN HERSCHEL'S drawing is probably our best record of its appearance at the 1835

Sir Isaac Newton.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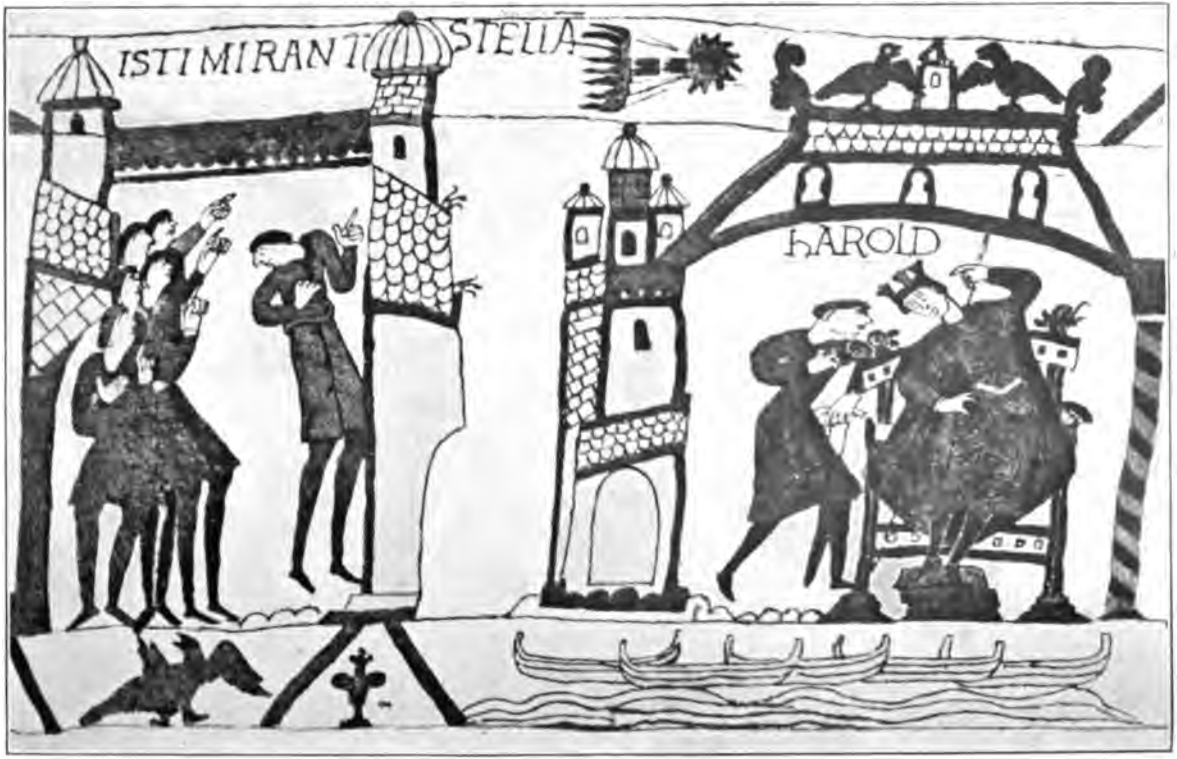
Sir Isaac Newton.



HALLEY'S COMET IN 1066, ON THE BAYEUX TAPESTRY.

return. Fortunately we now have photography to make permanent records of both its general and its detailed structure. The dry-plate puts down details which the eye cannot see, and it does the work with great accuracy. Since BARNARD's pioneer success in the photography of comets at the Lick Observatory, about 1890, no one seriously attempts to "draw" a comet. An inspection of the two photographs of Comet MOREHOUSE, just visible to the naked eye in the fall of 1908, will show the richness of structural detail, none of which could be seen in any existing telescope.

The long elliptical orbit of Halley's Comet and the nearly circular orbits of the Earth, *Mars, Jupiter, Saturn, Uranus,* and *Neptune* are represented in the figure—approximately to the correct scale; but it should be said that the plane of the comet's orbit makes an angle of 18° with the Earth's orbit plane. The comet's orbit therefore passes "through" the planetary orbits like the two adjacent links of a chain. The comet will approach within fifty-six million miles of the Sun, and then recede during thirty-eight years until it is far beyond *Neptune's* path. In perihelion it must travel thirty-four miles per second, but at the outer turning its speed will be less than one mile a second.

For purposes of description, it has been found convenient to divide the structure of a comet into three parts, as follows:—

1. The densest and brightest part near the center of the head, called the *nucleus.* Nearly all the mass of a typical comet resides in the nucleus.

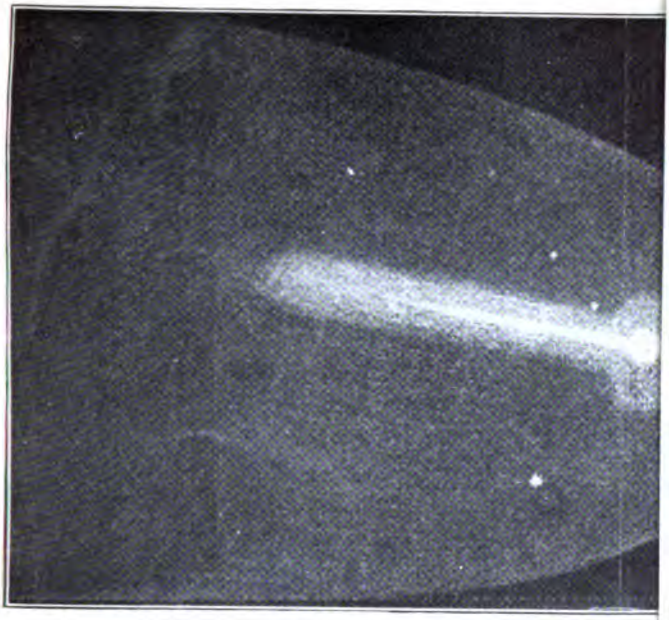
2. The *coma,* or envelope of low density surrounding the nucleus. In occasional comets the head consists entirely of coma without an apparent nucleus.

3. The *tail,* which always points approximately away from the Sun. When the comet is traveling toward the Sun the tail follows the head; when the comet is going away from the Sun, the tail precedes the head. This is illustrated in the drawing of the comet's orbit.

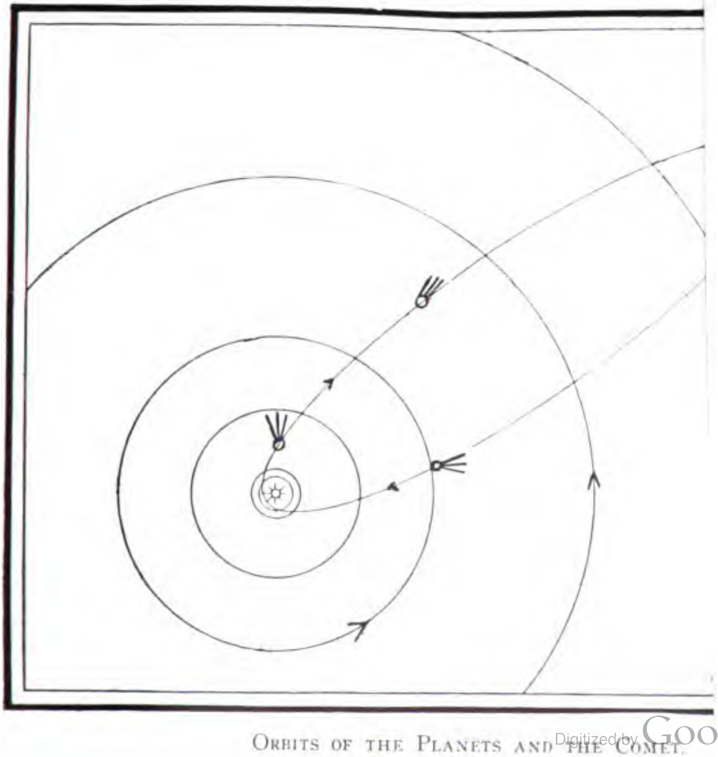
The fact that a comet's tail always points away from the Sun was early recognized. There could be no doubt that some force originating in the Sun was repellant to the materials composing the tail; but to determine the nature of this force defied us for generations.

Since the coming of photography and the accurate recording of details of comet structure utterly invisible to the eye, it has been possible to measure these motions. Comparisons of photographs of the same comet made two or three hours apart have shown that condensations and other structural forms have moved rapidly outward during the interval; only a few miles per second at first, but faster and faster as the distance out in the tail increased. Some observed speeds have been nearly fifty miles per second. Fifty miles per second is more than four million miles per day. If such motions exist, the constituents of the tail on one night are not the constituents of the tail of the following nights. Photographs of many comets taken on certain nights seem to bear no resemblance to those taken on the preceding or following night. The tails of the earlier dates have been driven off into space, scattered into invisibility, and entirely new tails have taken their places. The forces acting outwardly from the Sun and responsible for these expulsions were mysterious, and it is only within the last ten years that a fairly satisfactory theory has been established. Half a century ago the great physicist, CLERK-MAXWELL, in developing the electro-magnetic theory of light, deduced mathematically that the so-called light- and heat-waves, in striking upon any object, exert a pressure upon that object, very much as ocean waves falling upon the cliffs press against the obstructing rocks. The pressure due to light- and heat-waves, called radiation pressure, is extremely slight; so slight, in fact, that skilled experimenters were unable to detect its existence for many years. At last, about the year 1900, a Russian physicist, LEBEDEW, was able to observe this effect; and a few months later two American physicists, NICHOLS and HULL, were even more successful, for their accurate observations showed a satisfactory agreement with the demands of MAXWELL's theory.

Almost immediately the famous Swedish scientist, ARRHENIUS, expressed his belief that in this pressure of the Sun's heat- and light-waves we have the force which forms comets' tails. All the materials of a comet are necessarily attracted by the Sun, according to the law of gravitation. There can be no doubt that they are also acted upon by radiation pressure. The former seeks to draw all into the Sun, the latter to



Halley's Comet in 1835.
(By Sir John Herschel.)



Orbits of the Planets and the Comet.
(The smallest circle is the Earth's orbit.)

drive them into outer space. These are opposing forces. On the more massive parts of a comet, comprising the nucleus, radiation pressure is ineffective; and the nucleus moves along in its prescribed curve with remarkable precision. Not so with the finely divided materials of the coma and tail. Gravity acts as a function of a particle's mass, whereas radiation pressure's action is dependent upon the surface-area of a particle in relation to its mass. As particles become smaller and smaller a size will be reached such that these opposing forces will be precisely balanced. Particles larger than these will be drawn nearer to the Sun. Particles smaller will recede from the Sun.

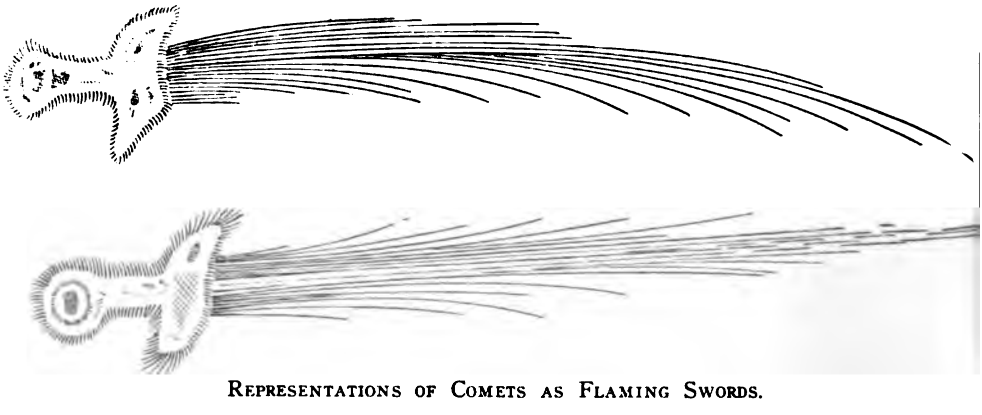
What seems to take place in a comet is something like this: Minute particles of solid matter or molecules of gas are expelled from the nucleus chiefly on the side toward the Sun, probably under the influence of the Sun's heat. Radiation pressure acts upon these particles to turn them directly away from the Sun; and the cloud of particles thus projected forms the tail. As the repellant forces act continuously, the particles must travel continuously faster; and this is the observed fact. Smaller and less dense particles must travel more rapidly than the larger and denser ones.

The constant expulsion of matter along the tail into outer space must of necessity cause a comet to grow smaller. Disintegration is continuous, and the tail at any moment is made up of materials lost forever from the nucleus. Several faint comets moving around the Sun in small orbits have been observed to be fainter at each successive return. Some have even disappeared entirely. Two such comets, now lost to view, reveal themselves only by virtue of meteor showers about the middle of August and the middle of November: the matter composing their nuclei has been scattered along their orbits, and the annual passing of the Earth across these orbits leads to collisions between the cometary fragments and our higher atmosphere. There is no reason to doubt that Halley's Comet is slowly disintegrating, and, after long ages, will suffer some such fate.

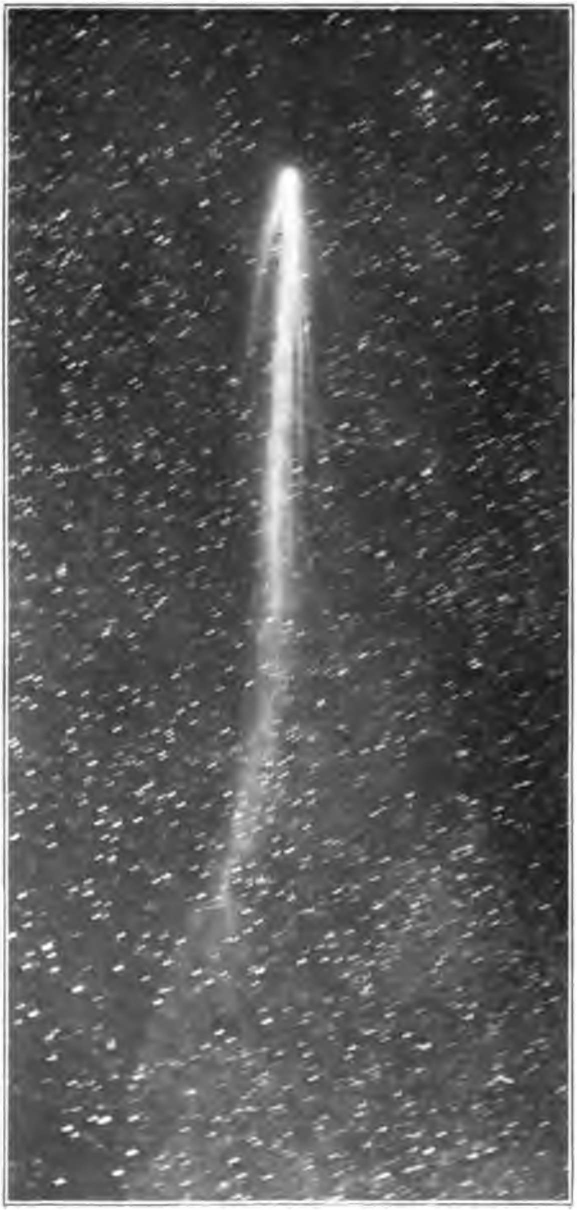
Our knowledge of the chemical composition of comets and of the state in which cometary matter exists is meager and unsatisfactory. A few give spectra very like that of our own Sun, indicating that they are shining by reflected sunlight, as the planets shine. Other comets send out their own light, almost exclusively, the radiations coming chiefly from carbon and cyanogen sources. Still others have mixed spectra, showing both inherent light and reflected light. Why comets shine by virtue of light within themselves is a mystery, for it is difficult to conceive that such attenuated bodies should have the heat of incandescence throughout their mass. Although many comets have volumes thousands of times as great as the Sun's volume, their total mass is insignificant even in comparison with that of the Earth; and such mass as they have is nearly all in the nucleus. The tails are surely less dense than the most perfect vacuum we can produce in the laboratory.

Halley's Comet is due to pass near the Earth in May, 1910,—perhaps within 10,000,000 miles of us. Let no one draw the inference that there may be a dangerous collision with the Earth, for such is not the case. Their paths are too widely separated. Even if the path of the comet were entirely unknown, we could say that the chance of a collision with the denser nucleus is so small as not to call for consideration. And if we should pass through the tail, there would be no evidence of such an encounter, unless it consist of a harmless meteor shower, for the tails of comets are certainly composed of exceedingly minute and widely scattered particles.

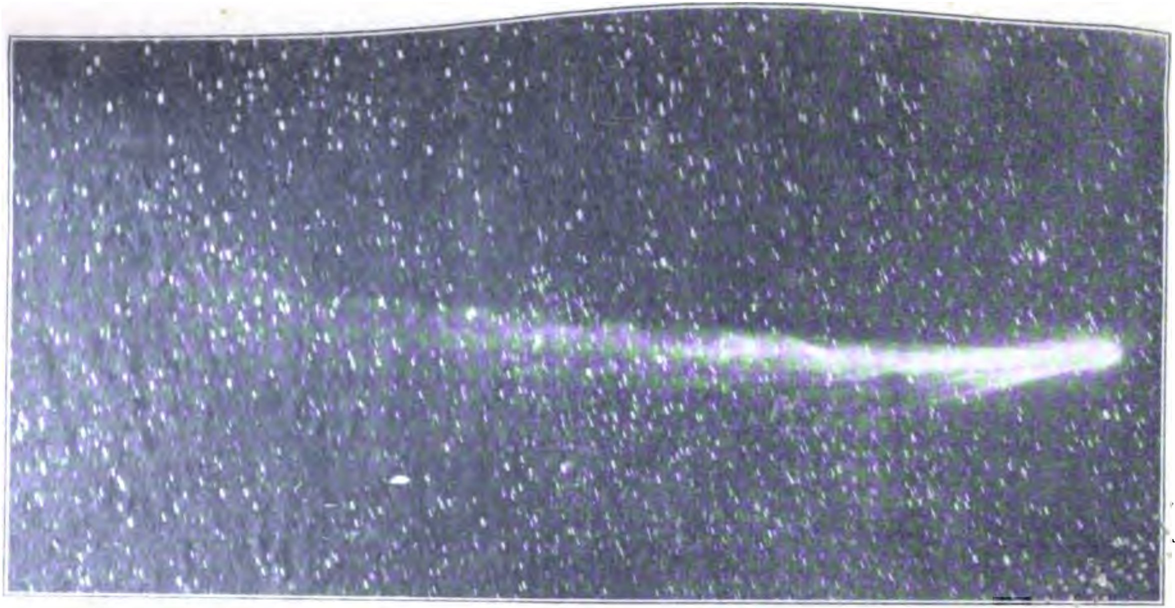
The ancients thought of comets as hairy objects, from the appearance of the tails; hence the origin of the term "comet," from the Greek *kometes,* signifying "long-haired." This belief prevailed certainly up to Halley's day and generation.



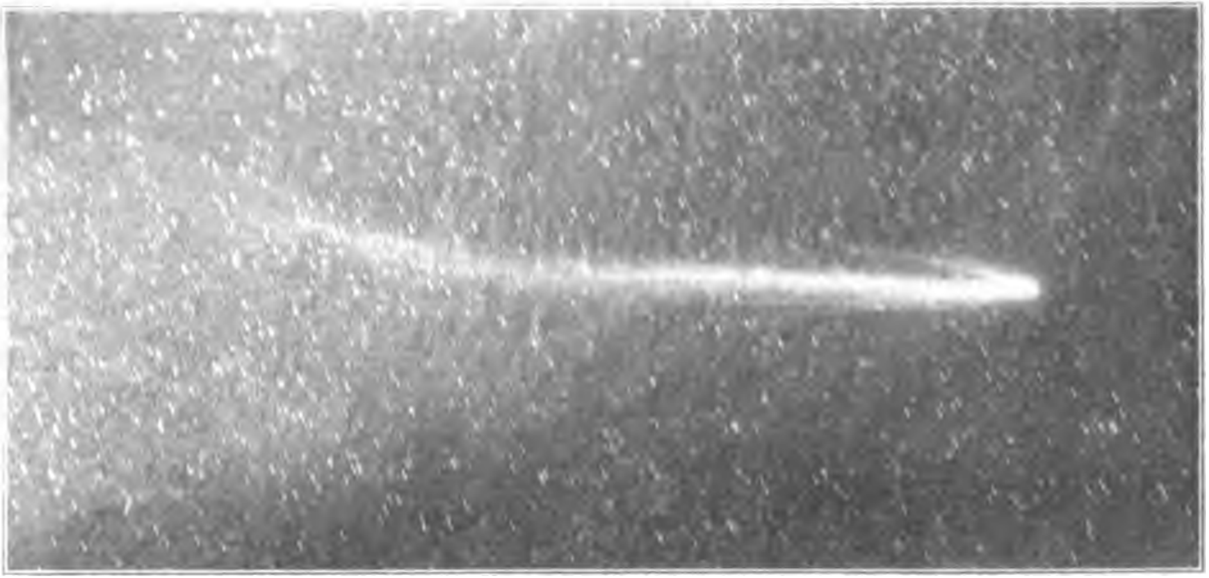
Representations of Comets as Flaming Swords.



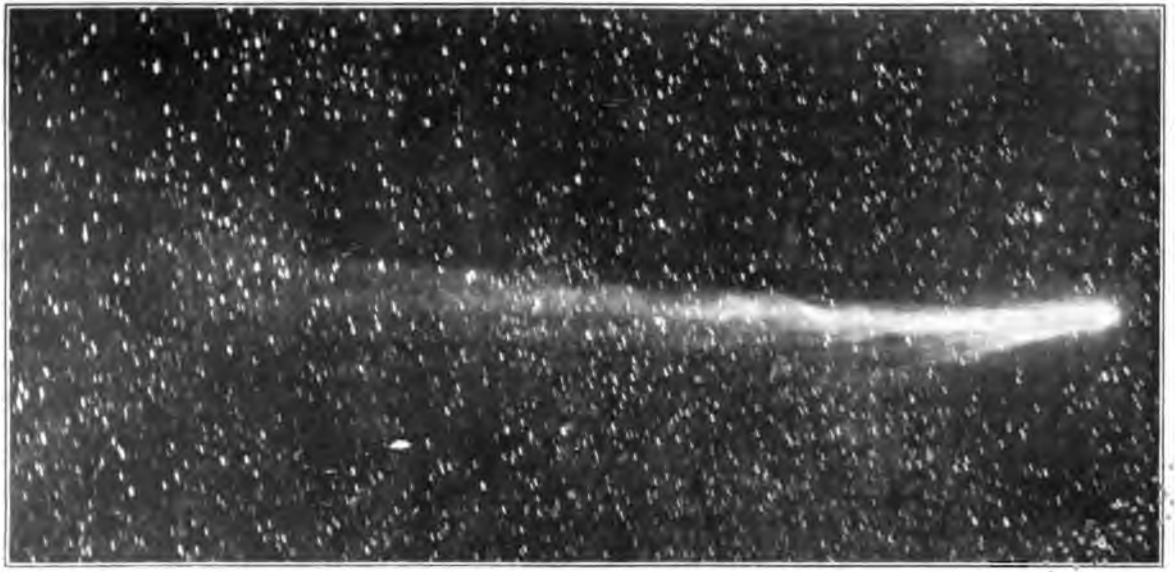
Comet Morehouse, Photographed at Lick Observatory, November 15, 1908.



Comet Morehouse, Photographed at Lick Observatory, November 18, 1908.



Comet Morehouse, Photographed at Lick Observatory, November 15, 1908.



Comet Morehouse, Photographed at Lick Observatory, November 18, 1908.

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All sorts of fantastic and fearsome ideas have attached to comets, from early historical times to near the close of the nineteenth century. The writer remembers clearly that his neighbors of thirty years ago considered comets to be messengers of disaster. The greatest comet of the nineteenth century, DONATI's of 1858, was the accredited forerunner of our Civil War. Medieval representations of comets as flaming swords were common.

In HOMER's "Iliad" XIX, 381, we read:—

> "Like the red star, that from his flaming hair
> Shakes down disease, pestilence and war."

From EVELYN's Diary of 1624:—

> " . . . the effect of that comet, 1618, still working in the prodigious revolutions now beginning in Europe, especially in Germany."

From MILTON's "Paradise Lost," II, 708-711:—

> " . . . and like a comet burn'd,
> That fires the length of Ophiuchus huge
> In th' Arctic sky, and from his horrid hair
> Shakes pestilence and war."

Not the least of the services of science to civilization has been the gradual emancipation of humanity from all fear of comets.

Astronomers will welcome the coming of Halley's Comet, full of hope that the photo-dry-plate, the spectroscope, and other ways and means of attack invented since its last visit in 1835 will enable them to remove something of the mystery of comets, the most mysterious of all celestial bodies.

PLANETARY PHENOMENA FOR NOVEMBER AND DECEMBER, 1909.

BY MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

Last Quarter..	Nov. 4,	$1^h\ 38^m$ P.M.	Last Quarter..	Dec. 4,	$8^h\ 12^m$ A.M.
Full Moon ...	" 12,	6 18 P.M.	Full Moon ...	" 12,	11 59 A.M.
First Quarter..	" 20,	9 29 A.M.	First Quarter..	" 19,	6 18 P.M.
New Moon ...	" 27,	12 51 A.M.	New Moon ...	" 26,	1 30 P.M.

There will be a total eclipse of the Moon on the night of November 26th-27th. The entire eclipse will be visible throughout the United States. The principal events of the eclipse occur as follows, Pacific time:—

Moon enters shadow	Nov.	26	11^{h}	11^{m}	P.M.
Total eclipse begins	"	27	12	14	A.M.
Middle of the eclipse	"	27	12	55	A.M.
Total eclipse ends	"	27	1	36	A.M.
Moon leaves shadow	"	27	2	38	A.M.

There will be a partial eclipse of the Sun on the afternoon of December 12th. No part of the eclipse will be visible in the United States, as the eclipse track is confined to the region near the South Pole. Southern Australia, New Zealand, and Tasmania will have a few minutes of partial eclipse.

The Sun reaches the winter solstice, its greatest distance south, December 22d, 3 A.M., Pacific time.

The Earth is in perihelion just after the close of the year on January 1st, 3 A.M., Pacific time.

Mercury on November 1st has just passed greatest west elongation, and is a morning star, rising about an hour and a half before sunrise, and the interval remains as great as an hour until near the middle of the month. It will be in good position for observation in the morning twilight for the first ten days of November. It passes superior conjunction and becomes an evening star on December 2d. By the end of the month it has moved far enough away from the Sun so that it can be seen in the evening twilight, and on December 31st it sets about an hour and a quarter after sunset.

Venus is an evening star, setting on November 1st about two and a quarter hours after sunset. This interval increases rapidly, and by the end of December it is more than three and one half hours. The planet reaches its greatest east elongation on December 2d, and its apparent distance from the Sun is then 47° 18′. It moves 62° eastward and 11° northward through *Sagittarius* and *Capricorn*. Toward the close of December it will have attained nearly its maximum brightness, and may be seen in the full daylight with the naked eye.

Mars is still in fine position for observation, not setting until nearly 3 A.M. on November 1st and nearly 1 A.M. on December 31st. It again took up its eastward motion at the end of October, and during November and December will move 19° eastward and 11° northward in the constellation *Pisces*. By

December 14th it will have reached the line at which it began its westward motion on August 23d, but it will be about 6° north of its August position. Its distance from the Earth in millions of miles increases from 49 on November 1st to 92 on December 31st, being on that date distant from us just a little less than the Earth's mean distance from the Sun. On November 1st its brightness is only a little more than half of its opposition brightness, and it will lose light rapidly, so that on December 31st it will be only one fourth as bright as it was on November 1st and only about one ninth as bright as it was at opposition. It will, however, still be conspicuous. Throughout the period *Mars* and *Saturn* will be in the same quarter of the heavens. On November 1st *Saturn* will be about 21° east of *Mars.* The more rapid motion of *Mars* will cause this distance to diminish to 13° by December 1st, and the two planets will come into conjunction on December 31st, *Mars* passing 3° 12′ north of *Saturn.*

Jupiter rises about 3:30 A.M. on November 1st and at about 12:30 A.M. on December 31st. It moves about 8° eastward and 4° southward in the western part of the constellation *Virgo* toward the first magnitude star *Spica, α Virginis,* and at the close of the period is 7° west and 6° north of the star.

Saturn is still in fine position for evening observation, remaining above the horizon until nearly 5 A.M. on November 1st and until after 12:30 A.M. on December 31st. It retrogrades, moves westward, until December 20th not quite 2°, and then moves eastward. It is in the constellation *Pisces.* Its conjunction with *Mars* on December 31st has already been noticed. As seen in the telescope the rings will appear to close up a little toward the end of the year.

Uranus is gradually being overtaken by the *Sun,* but may be seen in the southwestern sky in the evening. It moves about 3° eastward in the constellation *Sagittarius.* No bright star is near, but the planet comes to conjunction with *Venus* on November 23d, the latter being 2° 33′ south, and with *Mercury* on December 28th, the latter being 1° 44′ south.

Neptune is in *Gemini;* rises about 9:30 P.M. on November 1st and at about 5:30 on December 31st.

(SIXTY-SEVENTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded in duplicate to Mr. Zaccheus Daniel, of Princeton, New Jersey, for the discovery of an unexpected comet on June 15, 1909, and to M. A. Borrelly, of Marseilles, France, for the discovery of the same comet on June 14, 1909.

It was Mr. Daniel's notice of discovery, with observed position, which was first communicated to the astronomers of this and other countries by cable and telegraph.

W. W. Campbell,
Sidney D. Townley,
Heber D. Curtis,
Committee on the Comet-Medal.

San Francisco, Cal., October 8, 1909.

NOTES FROM PACIFIC COAST OBSERVATORIES.

Recent Progress in the Work of the D. O. Mills Expedition to the Southern Hemisphere.

During the past three years the work on the radial velocity survey of southern stars at the Observatory of the D. O. Mills Expedition has continued to proceed very favorably. At present the total number of plates taken at this station is about two thousand seven hundred. In 1908 Santiago was favored with an exceedingly fine and open winter season, so that it was possible to secure a much better representation than usual for this part of the program; there were about two hundred nights entirely clear in the year May, 1907, to May, 1908, with about sixty other nights of which at least half was available for work. Advices recently received from Santiago indicate that the past winter season has likewise been a very favorable one.

During the past two years most of the work has been done with the two-prism instrument; the limit of this spectrograph, without unduly prolonging exposures, is about photographic magnitude 7.0. At present, however, the program is simply to finish the work on all stars of visual magnitude 5.0 or brighter, leaving the considerable number of available early and solar type stars fainter than the fifth visual magnitude for later investigation.

While the method of refrigeration employed for cooling the mirror and obviating focal changes in the optical system was efficient for the purpose (cf. *Lick Observatory Bulletin,* No. 122), this is no longer used. The seeing for the first two hours after sunset at Santiago is rarely good enough to warrant attempting to gain what slight advantages there are, from the standpoint of spectroscopic work, in having the focus remain constant during this period, though for other classes of work some such method of focal control might be essential. Certain changes have been made by which it is now possible at all times to test the position of the focus and make the needed changes in the position of the spectrograph in a few seconds. This is made possible by connecting the screws which run the spectrograph up and down by means of bevel gears to a handle close to the observer. Occasionally, in the more unsettled weather conditions of the spring season, the focal length of the optical system will change by an amount too great to be allowed for by the existing amount of travel accorded to the spectrograph, which at present is a little over one inch. For such cases an attachment has been fitted by means of which the observer at the eye end can easily and quickly run the secondary mirror in or out a small distance to compensate for the abnormal change of focus. In the design of future spectrographs for use with large reflecting systems care should be taken to allow for ample travel for the spectrograph in the optical axis, though this attachment for moving the position of the secondary mirror of the Mills Reflector at Santiago works very easily and smoothly. A few other minor improvements have been made in the interests of easier observing; the comparison apparatus has been entirely re-made of steel, with provision for greater ease in adjustment than was allowed for in the former design.

The work of the radial velocity survey has occupied almost the entire time of the two observers, but a number of investigations have been made, or are in progress, along lines more or less allied to the main purpose of the expedition.

Forty-eight spectroscopic binaries have been announced to May, 1909, by Professor W. H. WRIGHT, Dr. H. K. PALMER, Dr. S. ALBRECHT, the writer, and Mr. GEORGE F. PADDOCK. Orbits have been computed by the writer for three of these—*α Carinæ, κ Velorum,* and *α Pavonis.* The binary character of perhaps fifteen more stars is suspected, but awaits the confirmation of further plates before being announced.

A number of stars having proper motions of $1''.0$ of arc or greater per year have been investigated, mainly with the one-prism instrument; during the course of this work three stars with radial velocities of unusual magnitude have been found:—

Cordoba Zones, 5^h 243	$+242^{km}$	per	second
Lacaille 2957	+100	"	"
Lacaille 8362	—132	"	"

Especial interest attaches to the first star on the list, whose proper motion of 8″.7 of arc per year is the greatest hitherto observed. It is believed that the radial velocities of C. Z. 5^h 243 and Lacaille 8362 are the largest observed up to date. KAPTEYN has pointed out that, of stars with considerable proper motion, there is a considerable preponderance of the later stellar types. A number of these stars have not hitherto been observed spectroscopically, and it is of interest to note that thus far in the investigation no case has occurred of a spectrum of the hydrogen or helium type.

During February and March, 1909, considerable time was devoted to securing an extended series of spectrographic and photographic observations of Comet MOREHOUSE.

The one-prism instrument has been employed by Mr. PADDOCK to secure data for the study of several southern variable stars.

Dr. J. H. MOORE arrived in Santiago to take charge of the station on June 5, 1909, and the writer left for California on June 17th, after three and a half years spent in Santiago. It is a pleasure to be able to express here my appreciation of the uniform courtesy and interest manifested by the Government of Chile and by the people of Santiago in the work of the D. O. Mills Expedition. A list of those who have at one time or another thus shown their interest in the expedition is here unnecessary, for I found no department of the government or the municipality of Santiago that was not ready at all times to render any possible assistance. Santiago is a cosmopolitan city of nearly four hundred thousand inhabitants, including about five thousand French, perhaps ten thousand Germans, and a growing colony of about eight hundred English and Americans; there is probably no city south of the equator more pleasant as a place of residence as regards both climatic conditions and social advantages.

HEBER D. CURTIS,
In charge of D. O. Mills Expedition, 1906-09.

ON THE SPECTRUM OF *MARS*.

When the spectrum of *Mars* was under observation extensively at Mount Hamilton in 1894, for the purpose of detecting the presence of water vapor in that planet's atmosphere, I realized that the water vapor in the Earth's atmosphere was and is the great obstacle in the way of success; and I then resolved to observe the spectrum of *Mars* from the summit of Mount Whitney[1], the highest point of land in the United States, when the planet should again come into a position favorable for the purpose. This would occur in August-September, 1909, when *Mars* would be near the Earth and high above the horizon at the time of year when Mount Whitney could be ascended with instruments.

Late in August, 1908, I ascended Mount Whitney, in order to determine the limiting sizes of instruments which could be transported over the rocky trail on the backs of pack animals, and to plan the living arrangements for the proposed expedition of 1909. I was accompanied by Director C. G. ABBOT, of the Smithsonian Institution Observatory, who was interested in the summit of Mount Whitney in connection with high-altitude studies of solar radiation, as Professor LANGLEY's pioneer expedition had been interested in 1881. We remained on the summit throughout the night of August 24, 1908. The readings of the dry- and wet-bulb thermometers obtained by Director ABBOT indicated that the conditions were extremely favorable for the solution of the proposed problem. Before leaving the summit I decided definitely that observations in 1909, requiring a residence of a week or more, should not be undertaken unless a building of some kind could be erected as a shelter in case of storm; and the question of ways and means was discussed. Director ABBOT suggested that the purposes of such a building might perhaps come within the scope of the Hodgkins Funds of the Smithsonian Institution. A few weeks later, after receiving my description of a building which would meet the needs of the proposed expedition, he was pleased to present the subject to Dr. C. D. WALCOTT, Secretary of the Smithsonian Institution, for consideration. Through the Secretary's lively interest, an appropriation to provide the building for the shelter of the 1909 and any worthy future expeditions was made.

As soon as the shelter was assured, Honorable WILLIAM H. CROCKER, Regent of the University of California, made generous private provision for all the expenses of the expedition from the Lick Observatory, University of California, including such pieces of new apparatus as were required to complete the equipment. This expedition was on the summit of Mount Whitney from August 28 to September 4, 1909. The instruments consisted of a 16-inch horizontal reflecting telescope and a suitable spectroscope. The observations, made on the nights of September 1st and 2d, were mainly photographic.

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[1] In the Sierra Nevada Mountains, California. Longitude, 118° 18′ W.; latitude, +36° 35′; altitude, 4,420 meters (14,501 feet).

The building erected by the Smithsonian Institution, under the supervision of Mr. G. F. MARSH, a public-spirited citizen of Lone Pine, was finished on the morning of our arrival. Its outside dimensions are eleven feet by thirty feet, and it is divided into three rooms. It has walls of stone and cement, doors and roof of steel, and windows of steel and wired-plate glass. No wood or other perishable material was used in its construction. The Crocker Expedition had abundant reason to appreciate the protection afforded by the building, as severe storms were encountered on the summit.

Water vapor in the atmosphere of any planet causes dark bands to be formed at certain definite positions in the spectrum of that planet; conspicuous bands if the water vapor is abundant; inconspicuous bands if the quantity is slight, as this, the only method known, is not a sensitive one.

The observer of *Mars* must look up through the Earth's atmosphere; and the great quantity of water vapor in our atmosphere, if the observer is near sea level or at ordinary altitudes, blots out the effect of any Martian vapor, making a solution of the problem impossible. By ascending Mount Whitney, altitude 14,501 feet, the Crocker Expedition placed itself above probably four-fifths or more of the Earth's water vapor. Further, the air on Mount Whitney was astonishingly dry during the time of the observations. With barometer 17⅔ inches, air temperature 29° Fahrenheit, and wet thermometer 17°, students of the atmosphere will recognize that the observers of *Mars* were looking through remarkably little terrestrial water vapor. Even this small quantity would be almost fatal to success if we did not have a fairly satisfactory method of eliminating its effects, as follows: Our Moon has no appreciable atmosphere. The lunar and Martian spectra will be affected alike by the water vapor in the earth's atmosphere.

These spectra are photographed, one immediately after the other while the conditions in our atmosphere remain unchanged, and with the Moon and *Mars* at the same altitude above the horizon so that their rays traverse equal paths in our atmosphere. If the vapor bands in the Martian spectrum are found to be stronger than in the lunar spectrum, *Mars* has water vapor in considerable quantities. If the bands in the two spectra are estimated to be equally strong, water vapor on *Mars* does not exist in sufficient quantities to be detected by the spectroscopic method. The latter condition was found to exist, when this method was applied under the superlatively favorable conditions existing on Mount Whitney. Both spectra were photographed when *Mars* and the Moon were near the horizon, again when they were at medium altitudes, and finally when they were 49° above the horizon. The best available vapor band, technically called *"a,"* was faint in both spectra when the bodies were low, fainter when the bodies were higher, and very faint when the bodies were at their highest; but for equal altitudes the *"a"* bands in the Martian and lunar spectra were equally intense, plainly signifying that the observed bands were due to water vapor in the Earth's atmosphere above the summit of Mount Whitney. This does not mean that *Mars* has no water vapor, but only that the quantity present, if any, must be very slight. Let us recall that we see *Mars* by reflected sunlight. The rays which reached our instruments passed from the Sun into the Martian atmosphere, for the most part down to the surface of the planet, and then out again to us, thus passing twice through the planet's atmosphere and any water vapor it may contain. Even with this multiplying effect on *Mars* the vapor bands in the Martian and lunar spectra were alike, and we conclude that any water vapor in the Martian atmosphere must have been less extensive than was contained in the rarified and remarkably dry air strata above Mount Whitney.

A detailed account of the Crocker Expedition, including descriptions of the spectra as photographed, and a discussion of the results obtained are in press as a *Lick Observatory Bulletin.*

The members of the party were Director W. W. CAMPBELL, Assistant Astronomer SEBASTIAN ALBRECHT, and Carpenter HOOVER, of Lick Observatory; Dr. JOHN J. MILLER, of San

Jose, who took charge of all questions relating to health; and Messrs. G. F. MARSH and W. L. SKINNER, of Lone Pine, California.

W. W. CAMPBELL.

NOTE ON THE MAGNETIC FIELD IN SUN-SPOTS.

In a preliminary note printed in *Publications of the Astronomical Society of the Pacific,* **20,** 220, 1908, it was shown that the evidence then available indicated the existence of a strong magnetic field in sun-spots. A summary of the results hitherto obtained in this investigation is given below:—

(1) In the spectra of sun-spots most of the Fraunhofer lines are widened, some are changed to doublets (incompletely resolved quadruplets), and some to triplets. Others probably have a still more complex structure.

(2) The component lines of spot doublets are circularly polarized in opposite directions (longitudinal effect in a magnetic field).

(3) Many lines not resolved in the spot spectrum are displaced when the Nicol (used with a Fresnel rhomb before the spectrograph slit) is rotated.

(4) When the Nicol, used with rhomb, is set at a certain angle, it transmits the red components of doublets in the spectrum of a right-handed vortex, and the violet components in a left-handed vortex.

(5) Although the larger spots in the northern and southern hemispheres of the Sun are usually found to be of opposite polarity, it frequently happens that spots of opposite polarity occur in the same hemisphere, sometimes in the same spot group.

(6) Triplets have been found in all our best photographs of spot spectra, including those taken when the spot was near the center of the Sun.

(7) The central component of such triplets is plane polarized, while the outer components are elliptically polarized.

(8) Many lines which are widened but not resolved in spot spectra can be shown to be triplets by cutting out the central component with a Nicol placed at a suitable angle.

(9) Under certain conditions, when a Nicol is used, the central line of a spot triplet is present on one side of the spot

and absent on the other. Rotation of the Nicol through 90° reverses the appearance, causing the line to appear on the side where it was previously absent and to disappear on the opposite side. This effect is provisionally attributed to the rotation of the plane of polarization of the plane polarized light emitted by the central line, when passing outward through the spot vapors.

(10) The width of the components of a spot triplet sometimes varies with the position of the Nicol. This may be the result of the combined effect of the rotation of the plane of polarization and the rapid decrease upward in the strength of the field above the spot.

(11) The intensity of the central line of spot triplets varies with the position of the spot on the Sun's surface, and is greatest near the limb.

(12) The intensity of the central line in a spot near the center of the Sun is such as to indicate that the lines of force of the magnetic field usually make a considerable angle with the solar radius passing through the spot.

(13) Lines which appear as doublets in the spot spectrum are found in the laboratory to be doublets when observed along the lines of force, and quadruplets when observed across the lines of force. With the dispersion available, such lines cannot be resolved into quadruplets in the spot spectrum.

(14) Spot triplets are found in the laboratory to be triplets when observed across the lines of force.

(15) Certain triplets and quadruplets of iron show nearly the same relative separation of their components in spot and laboratory.

(16) From the measurement of such lines, the maximum strength of the field is found to range from 2900 to 4500 C. G. S. units in different spots.

(17) The strength of the field is generally greatest near the center of the umbra and decreases gradually in intensity across the penumbra.

(18) An appreciable field is shown by certain lines to extend beyond the boundaries of the penumbra.

(19) Magnetic fields have also been found on the solar disk entirely outside of sun-spots.

(20) The doublets and triplets of iron give the strongest fields hitherto measured in sun-spots. The *D* lines of sodium and the *b* lines of magnesium, which are produced at a higher level in the solar atmosphere, indicate a much weaker field. The hydrogen lines over sun-spots, representing a still higher level, give no indication of a magnetic field. It therefore follows that the strength of the field in sun-spots rapidly decreases in passing upward from the surface of the photosphere.

(21) Preston's law, $\frac{\Delta\lambda}{\lambda^2} =$ const., is closely followed by iron doublets observed in the laboratory (using mean values of $\Delta\lambda$) and approximately so by spot doublets.

(22) The degree of widening of unresolved lines in the spot spectrum decreases rapidly from the red to the violet, and is roughly proportional to the separation of their components in the laboratory.

(23) A direct relationship appears to exist between the strengthening and the widening of lines in spot spectra.

(24) As the strength of the field is greatest at low levels, it appears probable that the electric vortex which produces the field lies within the photosphere.

(25) The strength of the field in sun-spots is not sufficient to account for magnetic storms on the earth.

Charts of the magnetic fields in sun-spots, showing their strength and polarity in all parts of a spot group and the surrounding regions, are made photographically as follows:—

Above the spectrograph slit a Fresnel rhomb (or a quarter-wave plate) and a Nicol prism are mounted, the position of the Nicol being such as to cut off one of the side components of a triplet. A series of exposures is then made, with the slit set across different parts of a spot group. The spot lines thus photographed are distorted, the red components appearing in spots of one polarity, the violet components in those of the opposite polarity. The displacement of the components from the normal position of the line is proportional to the strength of the field. It frequently happens that closely adjoining spots in the same group are of opposite polarity. In a recent case (September 25, 1909) a large spot was accompanied by four small spots, all lying within the same penumbra. The polarity of the magnetic field in the penumbra (on the side away from the small spots) was the same as that of the large spot. All of the small spots, however, were of opposite polarity. Between the large and small spots the magnetic fields of opposite polarity counteracted one another, reducing the strength of the resultant field to zero. This is shown on the photographs by the form of the lines: the red components bend sharply back from the position of maximum displacement over the large spot to the normal position of the line, where they cross to the violet side, returning again to normal in the region beyond the small spots.

By means of a series of parallel slits, the spectra of from six to ten sections of a spot group can be photographed simultaneously, in parallel strips on a single negative. A simple apparatus then permits images of any desired line in this negative to be photographed side by side, in the same relative positions as the parallel slits of the spectrograph. A photograph of the hydrogen flocculi, made with the *Hα* line, is then copied on the same plate.[1] The composite image shows the strength and polarity[2] of the magnetic fields along the lines occupied by the slits, and permits the relationship between the magnetic fields and the curvature of the streamers in the *Hα* vortices to be investigated. Results already obtained with provisional apparatus show this relationship to be an intimate one.

GEORGE E. HALE.

SPECTROGRAPHIC AND PHOTOGRAPHIC OBSERVATIONS OF COMET *c* 1908 (MOREHOUSE).[3]

So exceedingly faint was the nucleus of this comet that great difficulty was experienced in securing a slit spectrogram. An exposure was finally made with the one-prism spectrograph of the D. O. Mills Expedition extending over seven hours and twenty-nine minutes on the nights of February 24, 25, and 26, 1909. The width of the slit was 0.5^{mm} and precautions were taken to keep the temperature of the prism at the same point during all three exposure epochs and for several hours before commencing work. Only the strongest of the pairs, that at λ 4255-76, can be made out on this plate, and the resulting wave-lengths are λ 4254.2 and λ 4275.4.

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[1] Perfect registration is readily secured by the aid of a photograph of the spot group, reflected from the polished slit jaws into a camera, showing the exact positions of the slits with reference to the spots.

[2] With high dispersion the direction of the field can also be determined by the intensity of the central line of a triplet.

[3] Abstract of *Lick Observatory Bulletin*, No. 163.

Between February 24th and March 23d seventeen objective-prism spectrograms of the comet were secured, nearly all of them very faint. The resulting wave-lengths are:—

λ 3914.1	9 plates	
4002.1 4021.3	15 plates	
4254.0 (4276.0)	17 plates	
4526±	3 plates	Very difficult
4545.9 4570.2	16 plates	
4690.7 4716.3	4 plates	Difficult

In determining the wave-lengths given above, the line at λ 4276.0 was assumed as known.

Collecting the differences for the three strongest pairs of lines, λ 4002-21, λ 4254-76, λ 4546-70, together with the corresponding angles at the comet between the radius vector and the line connecting the comet with the Earth, we have:—

Observer.	Date.	$\Delta\lambda_1$	$\Delta\lambda_2$	$\Delta\lambda_3$	Angle.
DESLANDRES and BERNARD......	1908 Oct. 14	20	23	20 ±	39°.9
DESLANDRES and BOSLER........	Nov. 1	19.7	21.6	22.0	46 .3
CAMPBELL and ALBRECHT.......	Nov. 28	19.6	20.7	20.8	37 .2
CURTIS	1909 Feb. 25	18.5	22.0	24.5	39 .7
CURTIS	Mar. 21	19.4	22.5	23.8	35 .6

The objections to the explanation of the doubling of these lines as a Doppler-Fizeau effect have already been well put by CAMPBELL and ALBRECHT.[1] Assuming the actual velocities along the tail or transverse to the tail to have been the same on November 1, 1908, and March 21, 1909, the mean of the intervals for the three principal pairs of lines should have been about four tenth-meters greater, or less, respectively, on March 21st than on November 1st; whereas the observed intervals are not quite one tenth-meter greater on the latter date.

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[1] cf. *Lick Observatory Bulletins*, 5, 64, 1909.

The stronger objective-prism plates show the tail, though very faintly, to a distance of two to two and a half degrees from the head, and in all cases the tail is apparently a replica of the direct photographs taken at the same time, as far as can be made out on the small scale of the plates. In this respect a plate taken on March 20th is of especial interest; on this night the direct photograph shows a marked curve in the tail about half a degree from the head, a curve which is duplicated in each of the spectral images.

Twenty-eight direct photographs were also secured, the majority of these being taken with a portrait lens of 6⅛ inches aperture; many of these direct photographs show interesting evidences of the extraordinary activity which seems to have characterized this comet, both before and after perihelion.

Heber D. Curtis.

Thirteen Stars Having Variable Radial Velocities.[1]

In the progress of the work of the D. O. Mills Expedition to the southern hemisphere it has been found that the following stars have variable radial velocities:—

Star.	α	δ	Mag.	Type.	Range, km	Discoverer.
A.G.C. 8017	$6^h\ 28^m.9$	−31° 57′	5.7	B3A	+ 5 to + 41	Curtis
A.G.C. 9276	7 13 .3	−36 25	5.0	B3A	− 19 to + 41	Paddock
ε Volantis	8 7 .6	−68 19	4.5	B5A	− 29 to + 45	Curtis
H Velorum	8 53 .3	−52 21	4.8	B5A	− 4 to + 68	Paddock
β Crateris	11 6 .7	−22 17	4.5	A2F	− 7 to + 12	Paddock
A.G.C. 15975	11 36 .2	−61 32	4.9	G	− 4 to + 23	Paddock
θ^2 Crucis	11 59 .2	−62 36	5.0	B3A	− 19 to + 47	Paddock
A.G.C 19597	14 23 .7	−49 4	5.5	A2F	Both spectra	Curtis
e Lupi	15 6 .1	−44 8	4.9	B3A	− 8 to + 29	Curtis
ζ Trianguli Australis	16 17 .6	−69 52	4.9	G	− 2 to + 17	Curtis
δ^1 Telescopii	18 24 .4	−45 59	5.0	B8A	− 72 to + 27	Curtis
δ^2 Telescopii	18 24 .7	−45 49	5.3	B5A	− 9 to − 29	Curtis
ι Pisc. Australis	21 39 .0	−33 29	4.4	A	Both spectra	Curtis

With the exception of two plates on A.G.C. 15975, all the plates were taken with the two-prism spectrograph.

Heber D. Curtis.

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[1] Abstract of *Lick Observatory Bulletin*, No. 164.

Observations of Halley's Comet.

Search for Halley's Comet was begun early in September with the Crossley Reflector, although at this time the fogging effect of the moon rendered success more than doubtful. Owing to very high wind and poor observing conditions the nights of September 10th and 11th were not usable. The plate of September 12th shows the comet as a small, slightly elongated nebulous mass about five seconds of arc in diameter. The following positions have been derived from the photographs made with the Crossley Reflector:—

				Parallax factors.	
1909	P. S. T.	App. α	App. δ	α	δ
Sept. 12,	14^h 30^m 19^s	6^h 18^m 28^s.89	+ 17° 10′ 53″.9	9.655n	0.632
13,	15 42 20	18 37 .50	10 28 .2	9.563n	0.568
14,	15 29 41	18 45 .03	10 7 .4	9.578n	0.576
22,	15 8 45	19 4 .57	6 56 .5	9.555n	0.565
22,	16 8 52	19 4 .42	6 55 .6	9.416n	0.523

The position of September 14th rests upon five comparison stars, the others upon four each. On September 14th the magnitude was about 15.5.

Heber D. Curtis.

Note on the Pan-American Congress.

Dr. H. D. Curtis acted as the delegate of the University of Michigan to the first Pan-American Scientific Congress, held in Santiago from December 25, 1908, to January 5, 1909, presenting the following papers before the section of pure and applied mathematics:—

(1) Problemas astronómicos del hemisferio sur (Astronomical Problems of the Southern Hemisphere).

(2) Las velocidades radiales de estrellas australes con grandes movimientos propios (Radial Velocities of Southern Stars with Large Proper Motions).

(3) Estrellas dobles australes descubiertas con el espectroscopio por el Observatorio de la D. O. Mills Expedición (Spectroscopic Binaries Discovered at the Observatory of the D. O. Mills Expedition).

W. W. Campbell.

TELEGRAM.

LICK OBSERVATORY, September 14, 1909.

HARVARD COLLEGE OBSERVATORY,
Cambridge, Mass.

CAMPBELL and ALBRECHT compared spectra *Mars* and the Moon on Mount Whitney, September 1 and 2. Little *a* water-vapor bands estimated equal intensities and very faint. Zenith distance 42°, barometer 450 millimeters, air temperature —1° Centigrade, wet thermometer —8°. W. W. CAMPBELL.

Unfortunately "little" and "*a*" were transposed at some point in the transmission of the telegram to other observatories.

W. W. C.

REPORTS OF OBSERVATORIES.

LICK OBSERVATORY, MOUNT HAMILTON, CALIFORNIA.

This report covers the period January 1, 1908, to July 1, 1909. It is intended that only the more important items of the activity of the observatory shall be considered, and these quite untechnically.

The total solar eclipse of January 3, 1908, was observed by means of an expedition dispatched from the observatory through the generosity of Honorable WILLIAM H. CROCKER, regent of the University of California. A popular account of the expedition and its work has already appeared in these *Publications,*[1] and its general features need not be repeated here. In spite of clouds which interfered with carrying out the program during the first third of the total phase, subsequent studies of the photographs showed that the expedition met with an unusual measure of success.

Dr. PERRINE completed his detailed examination of the sixteen photographs, obtained with eight cameras, covering the region 9° by 28° extending in the direction of the Sun's equator. These photographs had for their purpose the detection of any existing intermercurial planet or planets. In the sudden downpour of rain immediately preceding totality it was not possible to protect everything, and a little water got into these cameras. Some of the photographs are marked by narrow bands where the rain water ran across them. Until after our return to Mount Hamilton it was thought the photographs were damaged to such an extent that the value of the intermercurial search was seriously impaired, and our public announcement embodied this view. It is gratifying to state that these fears were groundless. There are images of more than five hundred stars on the photographs, down to about the ninth magnitude; and, surprising to relate, the rain-streaked areas contain the images of all the known stars we expected to find thereon. All the images have been identified as those of well-known stars. In our opinion, the work of the three Crocker Expeditions, to observe the eclipses of 1901, 1905, and 1908, brings the observational side of the intermercurial planet problem—famous for half a century—definitely to a close. It is not contended that no planets will be found in the intermercurial region: it would not be especially surprising nor in contradiction to beliefs here expressed if small planets should be discovered at some future time; but it is confidently believed that their mass would be inadequate to account for the observed disturbances in the motion of *Mercury*.

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[1] **20**, 63, April, 1908.

The photographs of the solar corona obtained with cameras of 6′ and 40′ focal lengths are of great excellence. Opportunity has not been found to study these photographs as completely as we should like, and attention will be called to only one feature. A great number of coronal streamers appear to radiate from a common point near the eastern limb of the Sun (position angle 75°), as if thrown out by an explosion at the point, though it is not contended or even suggested that an explosion had actually occurred. The point of intersection of the streamers, obtained by prolonging them behind the Moon's disc, was estimated to be in position angle 75° and the distance from the Sun's center 13.′7 of arc. On comparing this position with the photographs of the hemisphere of the Sun turned toward us, as obtained by the Mount Wilson Solar Observatory on January 3d, 4th, and 5th, it was apparent that the vertex of the so-called disturbance was situated within the borders of a great group of sun-spots. It may be recalled that a similar cone of disturbance, as recorded on the Sumatra corona plates of 1901, appeared to have its vertex exactly over the large and only spot recorded on the photographs of the sun obtained on several days preceding and following the date of the eclipse; and that another radiating group of coronal streamers on the Spanish photographs had their estimated apex near, but apparently not in coincidence with, a prominent sun-spot. In view of these pieces of evidence, it is difficult to avoid the conclusion that the sun-spots and the coronal streamers referred to were closely related in origin.

Spectrograms of the corona obtained by Dr. Lewis and Director Campbell, using different instruments, recorded a large number of coronal bright lines, of which four observed by Dr. Lewis and two by Mr. Campbell are certainly new. The interpretation of the continuous spectrum of the corona is a difficult matter. The records are rendered very complex by the diffusion of light of the solar prominences and of the brilliant inner corona over the whole area of the spectrum. The dark-line spectrum believed to be due to photospheric light scattered by minute particles in the corona is visible very faintly, and only in the region of the corona well out from the Sun's surface. By far the greater part of the light gives a strictly continuous spectrum, and seems to be due to radiation from the coronal particles perhaps rendered incandescent by the overpowering heat of the Sun. The position of maximum intensity of continuous spectrum is displaced slightly toward the red from that of the normal solar spectrum, signifying the lower temperature of the corona.

The changing spectrum of the Sun's edge, as the edge was gradually uncovered by the Moon, was recorded successfully on a continuously moving sensitive plate. More than a thousand bright lines, changing into the dark lines of the ordinary solar spectrum, were impressed on the plate in lengths and at times such that they indicate the thicknesses and locations of the gaseous and vapor strata giving rise to them in the Sun's atmosphere. Four such photographs, obtained at the eclipses of 1899, 1900, 1905, and 1908, respectively, may be said to constitute a unique basis for the study of chemical stratification of the solar atmosphere. The moving plate has a great advantage over the fixed plate in recording the spectrum of the Sun's edge, in that the former gives a continuous record of all changes occurring, whereas the latter gives an integrated record for the brief period of exposure only.

From photometric observations of the Flint Island corona, Dr. PERRINE has deduced the following results, the unit of brightness being the light from one square minute of arc of flame of a Hefner standard lamp:—

Total actinic light of portion of corona observed	222 units
Intrinsic actinic brilliancy of corona	2.02
Intrinsic actinic brilliancy of sky near corona..	.0027
Ratio of intrinsic actinic brilliancy of the brightest parts of sky	744 to 1
Total actinic light of full Moon	2002 units
Intrinsic actinic brilliancy of full Moon	2.58
Ratio of total coronal to full Moon light......	0.111

A series of photographs for the study of polarization effects in the corona was obtained. The Rumford Committee of the

American Academy of Arts and Sciences has made a grant for the purchase of a photometer suitable for the measurement of these and other similar plates, and it is hoped that they may be subjected to quantitative analysis in the near future.

Dr. AITKEN has continued the double-star survey of the northern sky, according to the systematic plans described in my last report. It is expected that this survey, as carried on at Mount Hamilton, will extend to — 22° declination. About 90% of the survey has been completed; and given ordinary observing conditions in the following two winters and springs, the program should be completed. More than 3,300 close pairs of stars have been discovered as one result of this survey: 1,300 + by Professor HUSSEY and 2,000 + by Dr. AITKEN. The two components of each double are in fully 99% of the cases less than 5″ of arc apart.

It is scarcely necessary to say that the great value of this survey lies not in these discoveries themselves, but in the enormously increased opportunity which the discoveries will afford in the future study of double stars, in particular, and of the structure of the sidereal universe, in general. Holding the requirements of these studies in mind, the systematic qualities of the search are rigidly maintained; and at least two satisfactory micrometer measures of each pair are secured as promptly as practicable, before announcing the discovery. It is hoped, for example, that future computers of their orbits will have the great advantage of an accurate discovery position in each case.

About one hundred of the more important and more difficult of our well-known double stars are kept under observation by Dr. AITKEN, measures being made as often as they are needed. It has been found that the revolution period of 13 *Ceti* is only 7.4 years; next to that of *Delta Equulei* the shortest period known.

Astronomer TUCKER having been offered the superintendency of the Meridian Circle Station of the Carnegie Institution, in the Argentine Republic, the regents of the University were pleased to grant him leave of absence for the three academic years 1908-1911, in order that he might accept this highly honorable appointment. The remarkably large quantity of very accurate results secured by Mr. TUCKER during his fifteen years' residence on Mount Hamilton had given rise to a widespread feeling among the specialists in his subject that he was the man for the place. It was largely in response to this opinion that the director recommended the loan of Mr. TUCKER's services, involving as it did a serious interruption to our own program of observations. He left Mount Hamilton on May 1, 1908. His observations during the preceding four months, continuing his work of the preceding two years, related to the program for determining the extremely accurate positions of stars, based on fundamental methods as opposed to basing results upon a system of star positions already established with other instruments. The stars in his program are distributed nearly uniformly between 37° north and 37° south declination. Special stars are included for the purpose of determining the observer's personal errors as affected by his facing north or south while making the observations and by the direction of the apparent motion of the star through the field of view. Suitable stars for the investigation of atmospheric refraction were included, and likewise a list of stars to determine the effect of star magnitudes upon the personal equation. The reductions of the observations for the period of more than two years are well advanced, thanks to assistance afforded by the Carnegie Institution.

Much of Astronomer PERRINE's time has been devoted for several years to devising methods of measuring and reducing the long series of *Eros* photographs taken in 1900 with the Crossley reflector, for the determination of the solar parallax; and to superintending this work. The measurements and computations, based upon 525 photographs, were made by Mrs. MOORE and Miss HOBE, Carnegie Assistants, beginning with December 1, 1905. The results of the measurement were brought together by Dr. PERRINE last winter, and a critical discussion led to the most probable value of the solar parallax, $8''.8067 \pm 0''.0025$. This result is in remarkably good agreement with the longer series of observations secured at other stations. The details of the measurements and discussions will be brought out in a volume to be published soon by the Carnegie Institution.

During the period covered by this report about one hundred and fifty photographs were made with the Crossley reflector, chiefly by Dr. PERRINE and in part by Dr. ALBRECHT and others. The subjects included the faint satellites of *Jupiter*, nebulæ, star clusters, parallax objects, etc.

During the summers of 1907 and 1908 Mr. FATH made an extensive study of the zodiacal light with reference to polarization effects, the character of its spectrum, and its maximum extension northward from the ecliptic or Sun's equator. The spectrum observations are not yet ready for publication. The northern extension of the zodiacal light was observed satisfactorily, and there is left no doubt that it can be seen approximately 45° northward from the Sun, as viewed by a terrestrial observer.

Mr. FATH photographed the spectra of several spiral nebulæ and globular star clusters with a low dispersion instrument attached to the Crossley reflector. The text-books on astronomy ascribe in most cases a continuous spectrum to spiral nebulæ. Mr. FATH found that their spectra vary from those having principally bright lines, such as are found in the so-called gaseous nebulæ, to those containing only absorption lines of the solar type. No strictly continuous spectrum was observed. He confirmed in the strongest possible manner the earlier observations by SCHEINER and HUGGINS on the *Andromeda* nebula, removing any elements of doubt which may have attached to their results, to the effect that the spectrum of this object is of the solar type. The spectra of globular star clusters, including the great cluster in *Hercules*, are continuous, with a certain number of well-defined absorption lines. In general, stars of the so-called "F" type appear to predominate in the clusters. This type occupies a position about midway between the hydrogen stars and solar-type stars.

Micrometer observations of comets visible during the period have been obtained chiefly for the use of the Berkeley Astronomical Department in determining orbits. The spectrum of Comet Morehouse was studied by Messrs. CAMPBELL and ALBRECHT at Mount Hamilton, in the fall months of 1908, and by Astronomer CURTIS at the D. O. Mills Observatory in Chile, in the spring of 1909. The spectrum was essentially of a new type. The carbon and cyanogen bands usually visible in cometary spectra were relatively faint, and other sets of lines appearing in pairs were for the most part new and of remarkable strength. Readers are referred to *Lick Observatory Bulletins* 145 and 147 for detailed particulars. It was suggested by one noted astronomer that the doubling of the lines was a Doppler effect, due to relative motions in the observer's line of sight. Not only did this hypothesis seem extremely improbable, but our observations in the two hemispheres showed that it could not be true, for the varying angles under which the comet was observed should have been accompanied by corresponding variations in the intervals between the lines of the pairs. These intervals remained, on the contrary, essentially constant.

Miss GLANCY, fellow in the Lick Observatory, secured a splendid series of photographs of Comet Morehouse. Her measurements and discussion of the plates and the reproductions of a large number of the photographs are in process of publication. Dr. CURTIS's photographs of the comet and its spectrum will be published in the course of a few months.

Mr. DUNCAN, fellow in the Lick Observatory, made a systematic investigation of the two variable stars, Y *Sagittarii* and RT *Aurigæ*, and discussed the possible causes of the type of stellar variation represented by these stars. The basis of his studies consisted of spectrograms obtained with the one-prism and three-prism Mills spectrographs attached to the 36-inch refractor. The causes of the variation appear to be exceedingly complex, and several in number. Tidal disturbance, motion in a resisting medium, and an atmosphere of variable absorptive powers were considered. No one of these is in itself sufficient to explain the variations of brightness observed, and it is not improbable that two or more of them, along with other causes, are acting. The studies of a dozen stars belonging to this type of variation, made chiefly by fellows of the Lick Observatory, have furnished a very considerable amount of valuable evidence bearing on the problem. The most significant fact established, by Dr. ALBRECHT, is that the maximum brilliancy in each case studied occurs when the star has its greatest velocity of approach toward the observer. There is little reason to doubt that an observer viewing the star from any point in our universe would in every case have maximum brilliancy when the star was approaching him. Studies of other stars of the same type are extremely desirable, in order to make investigations of this type as a whole more effective.

The most extensive investigation under way is that of determining the radial velocities of the brighter stars by means of the Mills spectrograph attached to the 36-inch refractor, in the northern hemisphere, and by the D. O. Mills Expedition observing at Santiago, Chile, in accordance with a program determined upon by Mr. CAMPBELL in 1896. This program hopes to include all the stars whose visual magnitudes do not fall below 5.0 in the two hemispheres, using three-prism dispersion; with the addition of a considerable number of fainter stars in the southern hemisphere, using two-prism dispersion. The number of stars observed prior to June 1, 1909, at Mount Hamilton, is nearly 900, but approximately 200 of these have been temporarily rejected for observation with lower dispersion, because the lines in their spectra are too broad and ill-defined for accurate measurement. All the spectrograms secured prior to May, 1903, have been measured and reduced definitely; and about three fourths of those obtained between 1903 and 1909 have been similarly studied. In the southern hemisphere observations have been secured of 530 stars brighter than 5.0 and of about 150 stars fainter than 5.0 visual magnitude. The spectrograms of 148 stars observed by the D. O. Mills Expedition during its first period of work, in charge of Astronomer WRIGHT, have been completely measured and discussed, and both numerical results and accompanying text are entirely ready for the printer. Twenty-nine of the 148, or more than one in five, have been announced as spectroscopic binary stars. Of the spectrograms obtained during the second period of the expedition, in charge of Astronomer CURTIS, those made with three-prism dispersion have nearly all been measured and reduced; and those secured with two-prism dispersion have been submitted to approximate measurement and reduction.

Deducting stars observed in both hemispheres, the total number observed is 1,368.

The measurement and reduction of Mount Hamilton spectrograms have been invaluably assisted by grants from the Carnegie Institution.

In June, 1909, Dr. MOORE succeeded Dr. CURTIS as astronomer in charge of the D. O. Mills Expedition, the latter returning to Mount Hamilton to take up the work of Astronomer PERRINE, resigned.

The orbits of a considerable number of spectroscopic binary stars have been determined by Messrs. CURTIS, MOORE, and PLUMMER.

The record of spectroscopic binary stars discovered, observed, and investigated is complete to date, and it is our purpose to publish a second catalogue of spectroscopic binary stars next winter.

Volume VIII of the *Publications of the Lick Observatory,* containing heliogravure, hand-press reproductions of seventy of Professor KEELER'S photographs of nebulæ, taken with the Crossley reflector, was issued in December, 1908. The arduous task of preparing the glass positives of just the right density to meet the engravers' requirements and of reading the proofs was borne by Dr. PERRINE. The preparation of the copper plates, coupled with much experimental work, extended through nearly four years. We struggled to reproduce the delicate details of the structure in both the bright and faint regions of the nebular subject and to preserve the natural dark sky backgrounds. As the engravers acquired experience and skill in dealing with our photographs, better and better results were secured; but we were forced to recognize that only the original negatives or copies on glass will suffice for the most exacting scientific requirements. We are hoping to place a set of positive copies on glass in each of half a dozen scientific centers of population, where they will be accessible to all qualified students of the subject. The expenses of the KEELER Memorial Volume were so heavy that the work could not have been carried through but for the generous help of many friends of the observatory.

It has been held in mind for several years that our most pressing duty relates to the publication of extensive results of observations as yet unpublished; and an ambitious program of publication was formulated for the biennial period just begun. With the approval and support of the regents of the university, the legislature which recently adjourned was asked to appropriate funds to carry out my program of publication. For reasons not connected with the observatory and therefore quite beyond my control, the increased appropriations were not made. In fact, the actual appropriations for the biennial period are smaller than usual. Those available in the academic *year 1909-10 were consumed as soon as available* to meet deficits arising from printing for this and other departments of the university; and funds available for the year 1910-11 have been applied in good part to the same end. Efforts must be made to secure publication funds elsewhere. With the best of legislative intentions toward this observatory, we sometimes find it difficult to meet the expectations of other and distant astronomers in maintaining an international reputation on the basis of appropriations coming in meagerness from only one State of our own Nation—a generous State, whose finances were sorely tried by the catastrophe of April, 1906. The regents of the University of California, receiving their chief support from State funds, would gladly grant increased support to this department, I believe, if funds were available. The funds received from the university for the salaries of astronomers and astronomical assistants have been practically constant, since the beginning, in 1888, at $14,000 per annum. In the meantime the purchasing power of money has decreased fully one third.

Immediately following the completion of the KEELER Memorial Volume, we planned to begin with the reproduction of our long series of solar coronas, coronal spectra, etc., as illustrations for the proposed volume to contain the results of the Crocker Eclipse Expeditions to India, Georgia, Sumatra, Egypt, Spain, and Flint Island. It is hoped that efforts to secure funds for carrying on this work may soon be successful.

The number of *Lick Observatory Bulletins* issued to date is 160. This form of publication has been curtailed in the past three years to conform to *reduced* appropriations and greatly *increased* prices of printing. The special appropriation for the purpose has also borne the expense of printing and mailing brief *Bulletins* for the Berkeley Astronomical Department.

The half of a fire and earthquake-proof building, with several storage vaults to contain our invaluable collection of celestial photographs and rooms suitable for the development, enlargement, measurement, and study of the photographs, was erected late in the year 1907. The regents of the university recently appropriated funds to complete the building. The construction is at present under way and the building should be complete in October, 1909.

During years of normal rainfall the water supply, depending in the dry summer and fall months upon the storage capacity available, has been sufficient to meet the needs of households, photography, etc.; but in years of short rainfall it has been necessary to curtail the consumption. A serious shortage occurred in the fall and winter of 1908. The regents of the university recently authorized the construction of a steel storage tank with capacity of 160,000 gallons. This tank is under construction and should be available for the storing of water during the rainy months of the winter, for consumption in the latter half of 1910.

A beginning has been made in the planting of trees immediately around the summit occupied by the main buildings. Assistance has been received from the U. S. Forestry Bureau. It is hoped that the afforestation near the summit of the mountain may proceed on a liberal basis from year to year.

At the request of the Navy Department of the United States Government, we determined the longitude of the Naval Observatory at Mare Island, California, with reference to the assumed longitude of the Lick Observatory.

The Lick Observatory has suffered great loss in the departure of Astronomer CHARLES D. PERRINE to assume the directorship of the National Observatory of the Argentine Republic. Coming to Mount Hamilton in the capacity of secretary in March, 1893, Mr. PERRINE'S ability, energy, and interest carried him rapidly forward in an astronomical career. He was appointed astronomer in the Lick Observatory in 1905. The results of his work are well known to the readers of these *Publications*. Suffice it to say that his services were of unusually great efficiency, and the many honors which have come to him were fully earned. He left Mount Hamilton with the personal goodwill of all his associates. The chief attraction of his new post of duty lies in the opportunity which the largely undeveloped state of astronomy in the southern hemisphere presents. It is confidently expected that he will give a good account of his stewardship.

W. W. CAMPBELL,
Director.

June 30, 1909.

GENERAL NOTES.

The Meeting of the Astronomical and Astrophysical Society of America.—The tenth annual meeting of the Astronomical and Astrophysical Society of America was held at the Yerkes Observatory, Williams Bay, Wisconsin, August 18-21, 1909. The regular sessions for the presentation and discussion of papers and for the transaction of business by the society did not begin until Thursday morning, August 19th, but the Council of the society met at the observatory on Wednesday evening, and by the courtesy of Director FROST and Professor BURNHAM all members of the society who were present were given an opportunity to look through the 40-inch telescope, under Professor BURNHAM'S direction. Fortunately the sky was clear and the seeing fair, and, indeed, the society was favored with almost ideal weather throughout its sessions. The preceding week had been one of sultry and oppressive heat, but a heavy electrical storm on Monday night cleared the atmosphere, so that the following days of the week were only pleasantly warm and the nights for the most part clear.

This initial courtesy on the part of the staff of the Yerkes Observatory was only an indication of the cordial hospitality shown by them to the society throughout the following days. In the secretary's announcements of the meeting it was stated that members attending would be able to secure convenient quarters at Point Comfort on Lake Geneva, not far from the observatory buildings; but on our arrival we found the members of the staff insisting upon entertaining as many of us as their house-room would permit. The present writer had the very great pleasure of spending the three days as the guest of Professor and Mrs. BARNARD. Not content with this, we were all entertained at lunch each day by Mrs. FROST and the other ladies; Mrs. FROST'S house was open for a reception and tea at the close of the Thursday afternoon session; the observatory was thrown open for general inspection, under guidance of the staff, on Friday before the afternoon session, and at the close of that session, by courtesy of Mr. RYERSON and other residents on the lake shore, we were treated to a launch ride about Lake Geneva.

I have purposely mentioned the social features of the week before giving any account of the sessions themselves, for, after all, the most profitable part of such a meeting is the opportunity it offers for the better mutual acquaintance of workers in related lines of research and for the free interchange of views, and the social gatherings served these ends perhaps even better than the formal discussions of the papers. The fact that there was a very large attendance of members from all parts of the country—over fifty being registered—made this meeting an unusually favorable one for the promotion of acquaintanceship.

The papers themselves were of the greatest interest, and there were forty-two of them. Many of them, as, for example, PARKHURST'S "Precautions Necessary in Photographic Photometry," MOULTON'S "Some Considerations of Globular Star Clusters," and BARNARD'S "On the Photographs of Comet *c* 1908 (MOREHOUSE)," led to considerable discussion. The last-named paper, like many others, was fully illustrated by lantern slides, and opportunity was also given for examining the beautiful stereoscopic views that Professor BARNARD has prepared from his negatives of this comet.

It is impossible to give here even by title all the papers presented for our consideration. They treated, among other topics, of new designs of instruments, cameras, spectrographs, etc., new plans for tabulating the Moon's longitude, the problem of three bodies from the standpoint of spectroscopy, a proposed method of studying solar radiation at great altitudes, reports of progress in various researches, the spectrum of meteors, and the present needs of astronomy.

Aside from the formal papers, several other reports and resolutions were presented that aroused interesting discussions. Among these was a resolution relating to the current newspaper articles on signaling to *Mars*. It was finally decided that a statement should be prepared by a committee, the wording to be at their discretion, to the effect that in the present state of our knowledge it did not seem necessary or desirable for the society seriously to consider this matter.

The proposed change of name of the society to "The American Astronomical Society" was also discussed at some length, but the present name was retained by a decisive vote.

Professor COMSTOCK gave the report for the Committee on Comets. In brief, he stated that arrangements had been made that would make it possible to photograph Comet Halley from practically all longitudes on the Earth; for means will be forthcoming to bridge the great gap between the Lick and Solar observatories in California and observatories in Eastern Asia, by providing a temporary station at a suitable point in the Pacific Ocean. The committee had also secured promises that Professor BARNARD would outline a program of photographic observations, Professor FROST one of spectrographic observations, and Professor E. C. PICKERING one of photometric observations on this comet. These programs will be presented to astronomers in ample time to permit general co-operation in their execution.

Abstracts of all the papers presented will be printed in *Science* in the near future. It was also decided to issue a pamphlet giving a *résumé* of the history of the society and of the ten meetings so far held, the pamphlet to include also the constitution and by-laws of the society and a list of members.

R. G. AITKEN.

Two New Calculating Tables.—Dr. J. PETERS: Neue Rechentafeln für Multiplication und Division mit allen ein—bis vierstelligen Zahlen. G. REIMER, Berlin, 1909.

Dr. O. LOHSE: Tafeln für numerisches Rechnen mit Maschinen. W. ENGLEMANN, Leipzig, 1909.

It is the experience of all who find it necessary to carry through extended computations that it is scarcely possible to have at hand too many tables and other helps for the rapid performance of the different processes involved; it will be found that these two excellent tables will at once fill a distinct gap which has hitherto existed in the working library of every computer. Dr. PETER'S Rechentafeln contain the products of all one- and two-figure numbers by all numbers up to 9,999, making it possible to take out the product of two four-figure numbers from the same half-page, with only about one half the labor involved in performing the same process with CRELLE'S Tables. For all work, least squares, etc., necessitating the use of four figures, it will be found a great time-saver. Moreover, the numbers ending in a cipher are not omitted, as in the older edition of CRELLE, a convenience which will be appreciated by the practised computer, and a liberal use has been made of rulings and spacings so as to save the eye as far as possible from the strain incident to selecting figures from a solid, unbroken page.

LOHSE's Tafeln have been published to facilitate the greatly increasing use of the calculating machine. The first table gives the reciprocals of numbers to five places, thus making it possible to eliminate division, always more troublesome than multiplication with the calculating machine. Following this is a five-place table of the natural trigonometric functions to each hundredth of a degree; in this table all six functions are given—sine, cosecant, tangent, cotangent, secant, and cosine. Tables of square roots, and a convenient collection of trigonometrical and differential formulæ close the book. The arrangement and typography are excellent.

H. D. C.

Notes from "Science."—A bronze memorial tablet in honor of the late Dr. GEORGE W. HOUGH has been unveiled with appropriate exercises in the Dearborn Observatory of Northwestern University.

The University of Rochester, Rochester, New York, has received under the provisions of the will of the late Rear-Admiral WILLIAM HARKNESS, professor of mathematics, U. S. N., almost his entire large and valuable collection of astronomical and scientific instruments and a considerable part of his library. The instruments, including an Alvan Clark telescope, comprised the equipment for a private observatory he intended to erect. The devise of books included over sixteen hundred volumes and about seven thousand unbound periodicals and pamphlets. The university has placed the works on astronomy and physics in a separate section of its library, as the basis of a scientific department, to be known as the Harkness Scientific Library.

Mr. PHILIP FOX, hitherto instructor in astrophysics at the Yerkes Observatory, University of Chicago, assumed the duties of professor of astronomy in the Northwestern University and director of the Dearborn Observatory, Evanston, Illinois, on

September 1st. He is succeeded at the Yerkes Observatory by Dr. FREDERICK SLOCUM, for several years assistant professor of astronomy at Brown University, who has just returned from a year in Europe, principally spent at the Royal Astrophysical Observatory at Potsdam.

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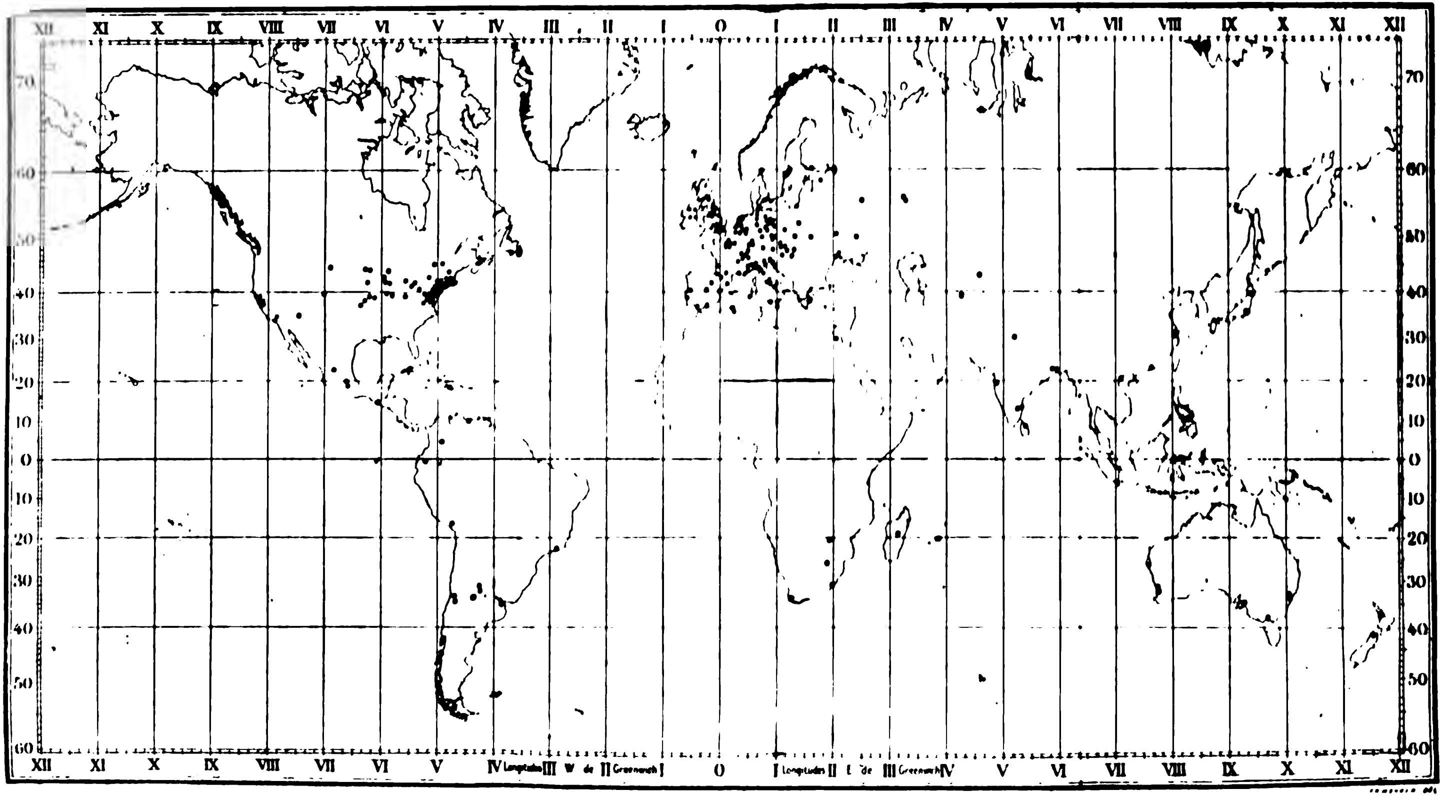
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FIGURE I. DISTRIBUTION OF THE PRINCIPAL OBSERVATORIES OF THE WORLD

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ASTRONOMICAL PROBLEMS OF THE SOUTHERN HEMISPHERE.

By HEBER D. CURTIS.

It is a natural result of the more recent development of the civilizations of the southern hemisphere that advances in the science of astronomy should likewise be less extensive than those made by the parent civilizations of the northern hemisphere. From the nature of the case, the southern hemisphere possesses relatively few astronomical records which can compare, in point of time, with those obtained for the northern skies during the last two centuries; and in the past, but to a less extent to-day, no small part of the progress made in mapping and studying the southern skies has been made by expeditions from the older foundations of Europe and America.

Probably the first observatory south of the equator which can be described as of a permanent character was that founded by Sir THOMAS BRISBANE in Paramatta, New South Wales, as a private observatory, in 1821; its period of activity extended over about ten years, and it was later incorporated with the Observatory of Sydney. An observatory was founded in Buenos Aires in 1822, but its period of activity was very short. Although the Observatory of the Cape of Good Hope was founded in 1820, its activity did not commence till 1829, the date of its completion; the extremely valuable and extensive work carried on here during the eighty years past give to it the unchallenged rank as the oldest permanent astronomical foundation in the southern hemisphere. At a later date we find the foundation of the Observatory of Santiago in 1856;

Melbourne, founded in Williamstown, Victoria, in 1853 and transferred to Melbourne in 1861; Adelaide, established in 1854; Córdoba, 1870; Arequipa in 1891, and others of more recent date. Among the early expeditions of a temporary character may be noted the visit of HALLEY to St. Helena in 1677; later we come to the appearance of the first large, systematic catalogue of the southern stars by LACAILLE as a result of his stay of four years at the Cape of Good Hope in the years 1751-55; the noteworthy investigations made at the same spot by Sir JOHN HERSCHEL from 1834 to 1838; the expedition sent to Santiago under charge of GILLISS in 1849; and others of more recent date to which attention will be called later.

The observatories in the southern part of the north temperate zone can extend their investigations in many lines of astronomical research to a distance of thirty degrees to the south of the celestial equator without great difficulty or loss of accuracy, but from this limit to the south pole we have a region amounting to about one fourth of the entire sky which, relatively to the northern skies, was almost as much a *terra incognita* seventy-five years ago as was Central Africa at the same date, and which to-day contains many virgin fields which offer rich returns to the exploring astronomer.

In the first great subdivision of astronomy, the astronomy of position, whose field is primarily the determination of the accurate positions of the fixed stars, the observed changes in these positions are so minute that the element of time becomes the most important factor to enable conclusions to be drawn from a given mass of observations as to the proper motions of the stars and the structure of the sidereal universe as a whole. Because of this relatively short time-factor since the earlier exact observations of the positions of the southern stars, the astronomy of precision of the southern hemisphere can not yet compete with the results from the northern heavens. Sir DAVID GILL has said, and there is doubtless no more competent authority to pronounce upon this point than he, that the state of our knowledge of the exact positions of the stars of the southern hemisphere is at least a century behind that of the northern hemisphere. Nevertheless, if we consider the results already secured in the exact cartography of the southern skies, and take into consideration also the researches in this field at present well under way, we may safely reach the conclusion that the coming twenty years will render our knowledge of southern star positions very little inferior to those of the northern skies, always excepting, in this conclusion, the disadvantage arising from the lack of early observations, a lack which will necessitate the accumulation of results for many years before our knowledge of southern proper motions can equal that of the northern stars.

In this task of bettering our knowledge of exact star positions in the southern hemisphere it is doubtless superfluous to mention here the excellent work that has been done in the past and is now in progress at a number of southern observatories, especially the extensive results from Córdoba and the Cape of Good Hope. In 1865 the Astronomische Gesellschaft undertook the extensive task of mapping, by means of exact meridian observations, all the stars in the sky down to the ninth magnitude. This work for the northern hemisphere and for some distance south of the celestial equator is now practically completed, and the work is advancing favorably for the more southerly portions of the sky at the observatories of Madras, Melbourne, and the Cape.

One of the most important programs in connection with the astronomy of precision of the southern hemisphere is that inaugurated last year under the auspices of the Carnegie Institution of Washington. It has for its object the measurement of the accurate positions of about twenty-five thousand stars in the southern skies in accordance with the system of Professor Boss, of Dudley Observatory. The instrument employed is the meridian circle of the Dudley Observatory, which has been used in the past for exactly similar work in the northern skies. The constants, graduation errors, etc., of this instrument have been so thoroughly investigated that doubtless no more efficient instrument exists to-day for this class of work. By the use of the same instrument, the same system of reductions, and to a certain extent even the same observers, it seems probable that the results of this program will afford us a far more exact binding together of the northern and southern skies in one homogeneous system than we possess to-day. The site has been selected at San Luis in the Argentine Republic. Professor TUCKER, of the Lick Observatory, is in charge of the Carnegie Observatory at San Luis, and recent advices state that the site seems to be a very favorable one for this class of work; it is hoped that the number of clear nights will average two hundred per year. The project involves about three years' work, and about seven observers and assistants are employed. Observations will be made throughout every clear night, "from sun to sun," with supplementary observations by day, and at this time the work of the observatory is doubtless in full swing.

In the years 1885-91, under the direction of Sir DAVID GILL, the Observatory of the Cape of Good Hope undertook an extensive photographic map of the southern skies, from declination — 19° to the south pole. The measurement of the positions of the stars on these plates was carried through by the disinterested and self-sacrificing labors of Professor KAPTEYN, and the publication in 1900 of the third and concluding volume of the great "Cape Photographic Durchmusterung" marked the completion of this monumental task. It contains the positions of 454,875 stars nearly to the tenth magnitude, and the positions are accurate to about one second of arc. It is an epoch-making work in the cartography of the southern heavens; in fact, until the completion of the "Astrographic Catalogue" no such complete and systematic photographic catalogue exists for the northern hemisphere. Naturally it can not compete, however, with the accuracy of the "Astrographic Charts"; those from Helsingfors, for example, having the small probable error of 0."11 for the mean of two measured star images.

Without doubt, however, the greatest problem in the cartography of the southern skies which awaits the observatories of the southern hemisphere is the completion of their respective shares in the great photographic map of the heavens mentioned above, which was inaugurated at the International Conference in Paris in 1887. As is well known, this plan, in its entirety, involved the construction of a photographic map of the entire sky down to the fourteenth stellar magnitude, for which about twenty-two thousand plates were to be taken, and the total number of the stars registered on the plates would probably reach twenty million. Supplementary to these charts the plan contemplated the publication of a great catalogue of perhaps two million stars down to the eleventh magnitude, based on plates of shorter exposure time. The task was apportioned among eighteen observatories in the two hemispheres. The observatories south of the equator which possess photographic equatorials of the uniform type adopted for the work are those at La Plata, Córdoba, the Cape, Santiago, Perth, Melbourne, and Sydney. It was proposed that the entire work be repeated in one hundred years. But so vast is the scope of this program that even in the northern hemisphere this project, whose value for the astronomy of position of the future can scarcely be over-estimated, has by no means made the progress anticipated for it at the time of its inception. Owing to the cost, only a few of the co-operating observatories have agreed to publish the great maps, and among southern observatories Perth has decided to take only the plates to the eleventh magnitude and to publish the resulting catalogue. Perth has taken all the plates in its zone, and has commenced the measures for the Catalogue. The section apportioned to the Cape of Good Hope is now nearly completed, both as to the taking of the plates and their measurement, and rapid progress is being made at Sydney, Melbourne, and Córdoba. Up to 1908 nothing had been done at La Plata or Santiago, though Dr. RISTENPART, recently appointed director of the National Observatory at Santiago, will make every effort for the prompt completion of the zone assigned to him; the work of taking the plates has already been begun under the direction of Dr. ZURHELLEN. It would seem that the publication of the costly maps might well be abandoned, for the plan adopted at Oxford of publishing only the co-ordinates of the stars would be far cheaper and fully as useful.

Excellent work has been done in determination of stellar parallax at the Cape of Good Hope, but the difficult field of work which has for its aim the determination of the distances of the stars by the heliometer or modern photographic methods is still practically untouched in the southern hemisphere. Parallaxes of only seventeen stars south of declination — 30° have been published, while north of this limit about three hundred parallaxes have been determined, many of them a number of times, by different observers and different methods.

In the interesting field of double stars, as is well known, HERSCHEL discovered many systems in the southern skies, and modern observers, as INNES, TAYLOR, and others, have materially augmented this number. During the past decade Professors AITKEN and HUSSEY have been making a very complete and systematic search for such doubles in the northern celestial hemisphere, with the result that several thousand new doubles have been discovered, many of them of great interest. They have reached the conclusion that at least one in every eighteen stars brighter than the ninth magnitude is a visual binary system. To these results we must add the evidence of the spectroscope that one in every five or six of the stars thus far examined is a spectroscopic double, and we have facts whose importance it is scarcely possible to over-estimate in their bearing on our theories of stellar evolution. Such systematic researches for the discovery of visual doubles are most urgently needed in the southern skies to round out the program which these astronomers have now nearly completed for the northern portions of the heavens. In this regard there is no doubt that the southern sky offers one of the richest and most promising fields of research existing to-day. BURNHAM's great "Catalogue of Double Stars," recently published by the Carnegie Institution, includes 13,665 pairs of stars and extends to south declination 31°. This eminent authority estimates that a century must pass before sufficient data can be collected to make a similar catalogue necessary for the southern hemisphere. INNES's "Reference Catalogue of Southern Double Stars"[1] contains 2,191 pairs between the equator and the south pole, but of this number about 925 are between the equator and BURNHAM's southern limit, nearly all of which have been discovered by observers in the northern hemisphere. A comparison of the number remaining, south of —31°, with the results from the northern skies will show clearly that there may well be two thousand double stars brighter than the ninth magnitude at present awaiting discovery in the southern hemisphere, to say nothing of the need for additional researches on the pairs already known.

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[1] Cape Annals, Vol. II, part II, 1899.

During the past ten years systematic observations have been made at six special stations in the northern hemisphere to study the small oscillations of the axis of the earth known as the variation of latitude. These stations are located at Mizusawa, Japan; Tschardjui, Asiatic Russia; Carloforte, Italy, and at Gaithersburg, Maryland; Cincinnati, Ohio, and Ukiah, California; and are all situated almost exactly on the parallel of north latitude 39° 8′. In 1905 the association which has this research in hand, Das Centralbureau der Internationalen Erdmessung, decided to extend this series of observations to the southern hemisphere, and the plans at first contemplated three stations: in Sydney, Australia; Capetown, Africa; and Santiago, Chile. It was pointed out, however, by Dr. HELMERT that better results could be secured, as far as the evaluation of the so-called Kimura-term in the latitude equation was concerned, by two stations placed as exactly as possible on opposite sides of the earth. Accordingly, after correspondence with authorities in Australia and the Argentine Republic, two sites were chosen in 1905 which satisfy this condition, and are, in addition, admirably situated as regards climatic advantages. Both are in south latitude 31° 55′ 15″, and differ 179° 36′ in their longitudes. The Australian installation is in charge of Dr. HESSEN, formerly of Berlin, and is located at Bayswater, West Australia, about four miles from Perth, the capital. The Argentine station is under the direction of Dr. LUIGI CARNERA, formerly occupied in similar observations at Carloforte, and is located at Oncativo, about forty-five miles from Córdoba.

Both of these stations commenced observations in 1906, and the work has been prosecuted with great energy since that date.[1] The results thus far secured are enabling us to draw more accurate conclusions with regard to these supplementary, exceedingly minute movements of the Earth's axis.

The formula for the variation of latitude is ordinarily expressed by the equation

$$\phi - \phi' = x \cos \lambda + y \sin \lambda + z,$$

where x and y are the components of the variation in the planes of zero longitude and that perpendicular to this, while the term z, called the Kimura-term from the Japanese astronomer who suggested its introduction, denotes that part of the variation which is common to all the stations, corresponding to an apparent movement of the center of gravity of the earth toward one or the other pole. The results from the northern stations have revealed the interesting fact that the value of z is periodic, with a period of one year, reaching its zero values about March 9th and September 12th, and its maximum and minimum values on June 10th and December 10th, these points coming, then, about ten days before the solstitial points. The preliminary results from the southern stations coincide almost exactly with those from the northern stations with respect to the magnitudes of x and y, and show, in addition, that the value of the z-term is of the same magnitude and algebraic sign as that derived from the northern results. This z-term is very small, oscillating only 0.″046 on each side of the mean, which, if real, would correspond to a movement of the center of gravity of the earth of about four and a half feet toward the north or the south pole. The temptation is very strong to seek a meteorological explanation for this small shift of the plane of the equator. The accumulation of snow and ice at one pole, together with the corresponding diminution at the other pole due to the melting in the summer season, would be perhaps sufficient to explain the shift, but, if this were the true and only explanation, it is difficult to see why the maxima and minima do not follow the solstitial points by a considerable interval of "lag," instead of preceding them by about ten days.[1] Moreover, the quantities involved are so extremely minute, such transcendental care is necessary in arranging and making the observations, and such pains to exclude in the investigation all possible sources of systematic error, that astronomers are by no means in accord as to the real existence of the z-term. BISKE has shown that a variation similar to that afforded by the z-term could arise as a result of inaccuracies in the adopted value of the solar nutation, and that future progressive changes in this value could result from similar slight errors in the adopted value of the lunar nutation. Quite recently Professor HIROYAMA, of Tokio, has subjected the results of the first four years of the latitude variation results to a careful analysis, and reached the conclusion that the z-term is probably a result of errors which may be classified as instrumental. He did not include in his researches, however, the results from the southern stations.

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[1] The observations at Bayswater were discontinued in January, 1909; the station at Oncativo has been taken over by the Government of the Argentine Republic.

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[1] Later studies seem to indicate that the maxima and minima in the z-term are slowly shifting.

Probably no more marked case of modern specialization in the science of astronomy, no more fitting example of minute and careful analysis, nor any better illustration of the mutual interdependence of fields of investigation apparently widely separated, can be found than this same subject of the variation of latitude. Long since, EULER, from purely mathematical considerations with regard to a rotating spheroid, showed that the axis of the earth should be subject to a minute oscillation, with a period of 305 days. In 1890-91 Professor KÜSTNER announced that this prediction had been confirmed by observation, but that the period was about 427 days. So minute is the movement that the poles shift from their mean position by less than thirty feet. Eight special observatories have been established, six in the northern hemisphere and two in the southern, and experienced observers are carefully accumulating the observations for the further study of this variation, determining from observations of the stars a periodic movement of the positions of the poles of the earth only a little greater than the distance from one wall of their small observatories to the other, and even showing, with some probability, that the earth's center of gravity oscillates once a year a distance of only a little over four feet toward one pole or the other. From these results DARWIN, HOUGH, LARMOR, and others have undertaken the investigation of the difference between the observed period of 427 days and that of 305 called for by theory, finding the explanation in the slight yielding of the earth, and have deduced the result that the earth, as a whole, must possess an effective rigidity a little greater than that of steel. In confirmation of these results, tidal students have found evidences, though very slight, of a minute tide with a period of 430 days. And in still another field these results may possibly prove of interest. No less an authority on earthquakes than Professor MILNE has expressed the opinion that earthquakes are more frequent at those epochs when the axis of the earth is farthest from its mean position, though this theory is not accepted by most seismologists.

In the wide field of stellar photometry, a very large proportion of our knowledge of the southern stars comes from the results of the Harvard photometric expeditions and particularly from its station at Arequipa, Peru. Through the visual results secured at Córdoba, the photographic magnitudes as given by the Cape Photographic Durchmusterung, and the long series of exact visual estimations made with the meridian photometer at Arequipa, we may say that, except in certain special studies on the fainter stars, the state of our knowledge of the relative brilliancy of the stars of the southern hemisphere is not inferior to that of the northern hemisphere.

From this station, too, has come far the largest proportion of what is known to-day with reference to the variable stars in the more southerly regions of the sky. Epoch-making in this branch is the discovery by Professor BAILEY of a very large number of variable stars in clusters. The Magellanic Clouds and other clusters in the southern hemisphere have alone given about two thousand new variable stars; the determination of the periods of all these and the study of the peculiarities in their variation will in itself furnish work for many years to come. Much remains to be done as well on the brighter variable stars of the southern hemisphere.

Through the excellent work at Arequipa, also, Harvard's extensive spectrographic surveys have been extended to the south pole. While it is certain that future studies with spectrographs of higher dispersion will bring forth many new facts with regard to stellar constitution, there is no doubt that Harvard's extensive surveys of the entire sky in the photometric and spectrographic fields will for decades be to the astrophysicist what the Bonn Durchmusterung has been to the worker in the astronomy of position.

As in the surveys just mentioned, the spectrograph was at first employed solely to determine the constituent elements of the Sun and the stars, but the application of the Doppler-Fizeau principle to the determination of a star's velocity in the line of sight from its spectrum has opened up to astronomy a field so vast that we scarcely dare to-day even to demark its boundaries. Few are the fields of astronomical research where the work in radial velocities is not making itself felt, and to-day we are furnished with the interesting spectacle of the oldest astronomy of position and the newer astronomy of the spectrum drawing closer and closer together for the solution of problems of sidereal structure. In order to determine the motion of our Sun through space many analyses have been made of the minute proper motions of the stars across our line of vision, but all such determinations are subject to some uncertainty because of the fact that the true distances of the stars whose proper motions are used in the analysis are, in general, very imperfectly known. On the other hand, the spectrograph gives us the velocity of a star in the line of sight, a velocity which, in stars possessing good spectral lines, is accurate within a few tenths of a kilometer per second, and which is entirely independent of the distance of the star from our system. For this reason it should be possible to determine from the radial velocities of a considerable number of stars well distributed over the entire sky a much more accurate value of the amount and the direction of the movement of the solar system through space.

For a complete solution of this problem, at which Dr. CAMPBELL and his associates have been working during the past fifteen years, it was necessary that radial velocities he secured for the stars in the southern hemisphere. This need was laid before Mr. D. O. MILLS, who, in 1902, generously gave the funds necessary for the installation on Mount San Cristóbal, Santiago, Chile, of a 37-inch reflecting telescope with the necessary spectrographic equipment, and in 1905 advanced further funds to continue the southern work for five years longer.

Up to date about 6,200 spectrograms have been taken at Mt. Hamilton and 2,700 by the D. O. Mills Expedition at Santiago, on nearly 1,400 stars. The northern portion of the program is nearly completed, and two years more should see the southern portions of the work essentially finished, though decades could well be used in investigating the "by-products" which have appeared in the course of the work, and other decades for the much needed extension of these researches to fainter stars. To give one instance only, at the Santiago station alone forty-eight spectroscopic binaries have been announced up to May, 1909, and to work up these binary systems adequately and compute their orbits would necessitate at least three years' work. One in every five or six of the northern stars examined has proved to be a binary, and nearly one in five of the stars observed by Professor WRIGHT during the first two years and a half of the work of the D. O. Mills Expedition. The discovery of so many spectroscopic binaries has greatly complicated the problem of determining the solar motion; moreover, several other complexities have of late been added to the analysis of the results. Recent investigations of the proper motions of the stars made by KAPTEYN, EDDINGTON, DYSON, SCHWARZSCHILD, and others, have shown that our universe is probably complex rather than homogeneous in respect to its structure, for there seem to be at least two fairly well marked directions of motions among the stars as a whole. Moreover, MONCK and KAPTEYN have pointed out that a considerable majority of stars possessing marked proper motions belong to those spectral types which show numerous lines of various elements, while the hydrogen and helium stars are relatively fixed in space. In connection with these facts a further complexity is brought in on the spectroscopic side through the unfortunate circumstance that it is not possible to derive accurate velocities for many of the hydrogen and helium stars, because of the wide and hazy character of their spectral lines. A simple solution will then perhaps be insufficient, on the assumption that all the velocities arrange themselves according to the probability curve; it would seem that a satisfactory conclusion can only be reached by a very careful combination of spectrographic results with due regard to all that the astronomy of position can give us with reference to "star-drift," proper motions, and variation of proper motion with type of spectrum.

Work on the determination of radial velocities has recently been inaugurated at the Observatory of the Cape of Good Hope, so that these two observatories, that at the Cape, and the D. O. Mills Expedition, have to themselves this rich and still only partly explored field, while in the northern hemisphere some ten observatories are at work on problems more or less allied to the determination of radial velocities.

In Figure I are shown the location of the principal observatories of the world; the cut is that given by STROOBANT in *Les Observatoires Astronomiques et les Astronomes,* Bruxelles, 1907, with the addition of a few recently established stations. The map shows, better than any description or tabulation, the overwhelming disproportion in the number of astronomical foundations in the northern and southern hemispheres.

Sufficient has been said to point out the great richness of the skies of the southern hemisphere as a field for the working astronomer, and note has been made of some of the lines of work in which there are great untouched regions awaiting the explorer. Numerous other points in which there is need for work in southern skies could easily be pointed out. Much work still remains to be done by those who are not possessed of powerful instruments in the study of the brighter variable stars and meteor radiants. Excellent photographs have been made with the Bruce Refractor at Arequipa, but the field of southern nebular photography with reflecting telescopes is almost untouched as yet, and there is no more urgent need for the astronomy of the southern hemisphere than the establishment of a large reflector to continue for the southern skies the work done by ROBERTS, KEELER, PERRINE, and others on the northern nebulæ and clusters, for the study of faint variable stars, for parallax investigations, and many other allied lines of research. A program of nebular photography has been inaugurated with the new reflector at Helwan, Egypt; its southern limit, however, will extend only to — 40°. The day must come, also, when there shall be established at some favorable point in the southern hemisphere a large solar observatory to carry on solar studies and investigations of the Sun's constant of heat in the southern summer season, thus supplementing the work of the northern solar observatories.

Above all, so few are the workers in this southern field compared with the men and the instruments attacking the problems of the northern skies, that some scheme of co-operation among southern observatories seems imperative, each one to devote its attention to some one line of work or some definite zone. Professor COOKE, of Perth, has recently pointed out the disadvantages arising from scattered and unsystematic observations in meridian circle work, and has announced that for the future all the efforts of Perth Observatory in determining stellar positions will be concentrated upon the zone from south declination thirty-one to forty-one degrees. Some such plan of co-operation and delimitation seems essential for the future progress of astronomy, and more particularly for the astronomy of the southern hemisphere; as Professor KAPTEYN has pointed out, the scope of this science to-day, with its millions of isolated units demanding study, is too vast for the combined efforts of all the observatories of the world, and he has accordingly suggested the well-known plan of limiting future studies to certain relatively small "selected areas," a plan which promises to be the best method of extending our finite knowledge in a realm that is practically infinite.

PLANETARY PHENOMENA FOR JANUARY AND FEBRUARY, 1910.

By MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

Last Quarter...	Jan. 3,	$5^h 27^m$ A.M.	Last Quarter..	Feb. 2,	$3^h 27^m$ A.M.
New Moon.....	" 11,	3 51 A.M.	New Moon....	" 9,	5 13 P.M.
First Quarter...	" 18,	2 21 A.M.	First Quarter..	" 16,	10 32 A.M.
Full Moon.....	" 25,	3 51 A.M.	Full Moon....	" 23,	7 36 P.M.

The Earth is in perihelion January 1st, 3^h A.M., Pacific time.

Mercury is an evening star until January 26th, 1^h A.M., when it passes inferior conjunction and becomes a morning star, remaining a morning star until early April. During the first half of January it will be a comparatively easy object for naked-eye view in the twilight soon after sunset, remaining above the horizon more than an hour, and at the time of greatest east elongation, January 10th, nearly an hour and one half after sunset. The greatest east elongation is rather a small one, as it occurs only eight days before the time of perihelion, and this makes rather a short period of visibility. After greatest elongation it moves rapidly toward inferior conjunction and then rapidly away from the Sun westward. It reaches greatest west elongation on February 19th, 26° 33′, a distance from the Sun not much less than the maximum, as it is then only eleven days from aphelion. During the latter half of February it may be seen under favorable weather conditions in the early morning twilight, as it rises somewhat more than an hour before sunrise. On February 27th it is in conjunction with *Venus*, the latter planet being 9° 18′ north of the former.

Venus is an evening star throughout January, passes inferior conjunction with the Sun on the morning of February 12th, and remains a morning star until it reaches superior conjunction on November 26th. On January 1st it sets about three and one-half hours after sunset. This interval diminishes to about three hours by the middle of the month, and at the end of the month it is only an hour and one half. It can be seen as an evening star for only a few days in February, as it rapidly nears inferior conjunction. By February 20th it rises more than an hour before sunrise and this interval is increased by half an hour before the end of the month. The period of invisibility on account of proximity to the Sun is much less than it usually is, for the reason that the planet passes the point in its orbit farthest north from the ecliptic on February 26th, and at the time of inferior conjunction is 8° north of the Sun. It is barely possible that it may be seen both as evening and morning star on the same day. During January the planet will be very bright, reaching its maximum at the end of the first week of the month. For some weeks it will be bright enough to be seen in full daylight by the naked eye.

Mars is still in good position for observation, as it remains above the horizon until after midnight throughout the two months' period, and may be easily seen in the southern or southwestern part of the heavens on any clear evening. It moves 34° eastward and 12° northward among the stars from the eastern part of *Pisces* through *Aries* to the western part of *Taurus*. On January 1st its distance from the Earth is about the same as the Earth's mean distance from the Sun, but the distance is increasing very rapidly, and by the end of February it is more than fifty per cent greater than it was in early January. Its brightness is of course greatly diminished from that it had in the early autumn of 1909, being on January 1st less than one sixth of the brightness at opposition, and it will lose more than half of this by the end of February. But it will still be as bright or brighter than a standard first magnitude star; and there will not be the slightest difficulty in recognizing it, as it is in a region where there are no bright stars, and its peculiar ruddy color will also aid in identifying it.

Jupiter rises shortly after midnight on January 1st, and at about 8^h 30^m P.M. on February 28th. During the latter part of the period it will be in fair position for observation in the southeastern sky late in the evening. It is in the western part of the constellation *Virgo* and moves about one degree eastward until January 30th, and during February retogrades, moves westward, about the same amount.

Saturn is very close to *Mars,* about 3° south, on January 1st, setting not long after midnight, but its eastward motion among the stars is comparatively slow, and the planets rapidly separate. By the end of February *Saturn* sets shortly after 9 P.M. It is in the constellation *Pisces* and moves about 4° eastward and northward during the two months.

Uranus passed conjunction with the Sun in December, 1909, and is a morning star, but during the greater part of the period is too near the Sun to be seen. At the end of February it rises about 2^h 30^m A.M. It moves about 3° eastward in the constellation *Sagittarius* during the two months.

Neptune comes to opposition with the Sun on January 8th, and is then above the horizon throughout the entire night; but it is too faint to be seen without a telescope. It moves westward slowly in the constellation *Gemini.*

BY-LAWS

OF THE

ASTRONOMICAL SOCIETY OF THE PACIFIC.

ARTICLE I.

This Society shall be styled the ASTRONOMICAL SOCIETY OF THE PACIFIC. Its object shall be to advance the Science of Astronomy, and to diffuse information concerning it.

ARTICLE II.

This Society shall consist of patrons, active members and life members, to be elected by the Board of Directors.

1. Persons who render distinguished services to the Society may be designated as patrons of the Society. The consenting votes of eight members of the Board of Directors shall be necessary for election to this status. Such election shall carry with it election to life membership in the Society and the privileges attached thereto.

2. Active members shall consist of persons who shall have been elected to membership and shall have paid their dues as hereinafter provided.

3. Life members shall consist of persons who shall have been elected to life membership and shall have paid $50 (fifty dollars) to the Treasurer of the Society.

4. A certain number of observatories, academies of science, astronomical societies, institutions of learning, etc., not to exceed one hundred, shall be designated by the Board of Directors as Corresponding Institutions, and they shall receive the Publications of this Society in exchange or otherwise.

ARTICLE III.

At each annual election there shall be elected a Board of eleven Directors, and a Committee on Publication, consisting of three members. The officers of this Society shall be a President, three Vice-Presidents, two Secretaries, and a Treasurer. The Directors shall organize immediately after their election, and elect from their number the officers of the Society. They may also appoint a Librarian, and such other assistants as may be required. The Directors shall fill by appointment any vacancies which may occur after the annual election.

The Library of the Society shall be kept in San Francisco, and shall be open to the use of all the members.

ARTICLE IV.

The President, or, in his absence, one of the three Vice-Presidents, or, in the absence of both the President and the Vice-Presidents, any member whom the Society may appoint, shall preside at the meetings of the Society. It shall be the duty of the President to preserve order, to regulate the proceedings of the meetings, and to have a general supervision of the affairs of the Society. The President is, *ex-officio,* a member of all Committees of the Board of Directors.

ARTICLE V.

The Secretaries shall keep, and have the custody of, the records; they shall have the custody of all other property of the Society, excepting the money thereof; they shall give timely notice of the time and place of meetings; they shall keep in books a neat and accurate record of all orders and proceedings of the Society, and properly index them; they shall conduct the correspondence of the Society; they shall preserve and index the originals of all communications addressed to the Society; and keep a copy of all their letters, properly indexed; and they shall prepare for publication an accurate summary of the transactions of the Society at each of its meetings.

ARTICLE VI.

The Treasurer shall receive and deposit in such bank as may be designated by the Directors, to the credit of the Society, all donations and bequests of money and all other sums belonging to the Society. He shall keep an account of all money received and paid by him, and at the annual meetings shall render a particular statement of the same to the Society. Money shall be paid by him only on the written order of the Finance Committee of the Board of Directors. He shall give such bonds as may be required by the Board of Directors.

ARTICLE VII.

Candidates for active or life membership may be proposed by any member of the Society to either of the Secretaries, in writing. A list of such candidates shall be certified to the Board of Directors by the Secretaries at each of their meetings, in writing. A majority (not less than three) of the Directors present at any such meeting shall be required for election.

ARTICLE VIII.

Each active member shall pay as annual dues, the sum of five dollars, due on the first day of January of each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three-fourths only of such dues; when elected during the third quarter, he shall pay one-half only of such dues; when elected during the last quarter, he shall pay one-fourth only of such dues; provided, however, that one-half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. No one shall be deemed an active member, or receive a diploma, until he has signed the register of members, or accepted his election to membership in writing, and paid his dues for the current year. Any member may be released from annual dues by the payment of fifty dollars at one time, and placed on the roll of life members by the vote of the Board of Directors. Any failure on the part of a member to pay his dues within six months after the time the same shall become payable, may, at the discretion of the Board of Directors, be considered equivalent to a resignation.

ARTICLE IX.

The annual meeting of this Society shall be held on the last Saturday in March, at eight o'clock P. M., at the rooms of the Society in San Francisco; and meetings shall be held for the ordinary transactions and purposes of the Society, as follows:—

A meeting shall be held in the library of the Lick Observatory at a suitable hour on the last Saturday of August; and meetings shall be held in the rooms of the Society, in San Francisco, at eight o'clock P. M., on the last Saturdays of January, March, June and November; but it shall be within the discretion of the President to designate other places of meeting, in San Francisco or vicinity, for the meetings of January, June and November, whenever, in his opinion, such change will be to the advantage of the Society.

A special meeting may be called by the President, or, in his absence or disability, by one of the Vice-Presidents, or, in the absence or disability of both the President and the Vice-Presidents, by the Secretary, on the written requisition of ten active or life members; and the object of such meeting shall be stated in the notice by which it is called.

The annual election shall be held on the day of the annual meeting, between the hours of 8:15 and 9 P. M.

No member shall be permitted to vote at any meeting of the Society who has not paid all his dues for past and current years. There shall be no voting by proxy.

ARTICLE X.

Fifteen active or life members shall be a quorum for the transaction of business.

ARTICLE XI.

No papers or manuscripts shall be published by the Society without the consent of the Directors. Any motion to print an address, or other paper read before the Society, or any other matter belonging to the Society, shall be referred to the Committee on Publication, who shall report to the Directors. The Committee on Publication may make suggestions to the Directors, from time to time, with reference to the publication of such papers as in their judgment should be published by the Society; and this Committee shall have the care, direction and supervision of the publication of all papers which the Directors may authorize to have published.

Members of the Society shall receive all the Publications of the Society free of charge.

ARTICLE XII.

This Society may, by a vote of a majority of all its active and life members, become a branch of an American Astronomical Society, should one be formed.

ARTICLE XIII.

It shall be the duty of the Directors, in case any circumstances shall arise likely to endanger the harmony, welfare or good order of the Society, to call a special meeting of the Society; and if, at such meeting, after an examination of the charges, and hearing the accused, who shall have personal notice of such proceedings, it shall be proposed that the offending member or members shall be expelled, a vote by ballot shall be taken, and if two thirds of the members present vote in favor thereof, the offending member or members shall be expelled.

ARTICLE XIV.

The Directors shall meet half an hour before the stated time of each regular meeting, and at such other times as they may appoint. The President, or, in his absence, any one of the Vice-Presidents, may call special meetings of the Board of Directors at any time. Notice of the time and place of such meeting shall be given by the Secretaries, by depositing in the post-office at San Francisco a notice of the time and place, addressed to each Director personally, at his last known place of residence, with the postage thereon prepaid, six days before the time of meeting.

ARTICLE XV.

The By-Laws may be amended at any time by a consenting vote of nine members of the Board of Directors at any duly called meeting thereof.

ARTICLE XVI.

In order to increase the usefulness of the Society, any groups of its members residing in the same neighborhood (except in the City and County of San Francisco, State of California,) are authorized to form local organizations which shall be known as "The ——— Section of the Astronomical Society of the Pacific."

No Section shall be formed except by the consent of the Board of Directors of the parent Society.

The proceedings of such Sections may be printed in the Publications of the Astronomical Society of the Pacific, either in full or in abstract, and the parent Society shall not be in any way responsible for publications made elsewhere.

No person not a member of this Society in good standing shall be eligible to membership in a Section, nor shall membership in a Section interfere in any way with the status of the person as a member of this Society.

The special expenses of each Section shall be borne by the group of members composing it, and this Society shall not be liable for any debts incurred by any Section.

STATUTES FOR THE BESTOWAL OF THE BRUCE MEDAL OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC.

I. A medal is founded by Miss CATHERINE WOLFE BRUCE, of New York, to be given, not oftener than once a year, for distinguished services to astronomy. The medal is international in character, and it may be awarded to a citizen of any country, and to a person of either sex.

II. The cost of the medal is to be met from the interest of the *Bruce Medal Fund* of $2500. The capital of this fund is not to be impaired. Unexpended interest is to be added to the capital to become an integral part thereof.

III. The medal is to be of gold. The *obverse* is to bear the Seal of the Astronomical Society of the Pacific. The *reverse* is to bear an inscription as follows: THIS MEDAL, FOUNDED A. D. MDCCCXCVII, BY CATHERINE WOLFE BRUCE, IS PRESENTED TO .... FOR DISTINGUISHED SERVICES TO ASTRONOMY .... (date in years).

IV. The Bruce Medal is not to be given twice to the same individual.

V. On the first of September of every year one of the Secretaries of the Astronomical Society of the Pacific is to address an official letter to the Director of each of the following Observatories, namely:—

The Harvard College Observatory,	The Observatory of Berlin,
The Lick Observatory,	The Observatory of Greenwich,
The Yerkes Observatory,	The Observatory of Paris,

enclosing the statutes relating to the Bruce Medal, and requesting each of the six Directors just named to nominate not to exceed three Astronomers worthy to receive the medal for the ensuing year.*

The replies of the said Directors are not to be communicated by the Secretary to any person until the first of November, when a list containing the names of the Astronomers so nominated is to be certified, in writing, by the Secretary, to each of the eleven Directors of the Astronomical Society of the Pacific; and a special meeting of the Directors called for the last Saturday in November, at 2 P. M. At that meeting these Statutes are to be read; and the original letters from the Directors of the Observatories are to be submitted by the Secretary, and afterwards sealed in an envelope and deposited in the archives of the Society, not thereafter to be opened except by a formal resolution of the Directors, passed at a regular meeting. All such letters and nominations are to be regarded as confidential by all who are knowing to them.

VI. The Directors of the Astronomical Society of the Pacific, at the special meeting aforesaid, may vote in person or by written proxy.

The medal is not to be awarded unless the votes of at least six Directors are cast at this meeting. It may be awarded to any individual named in the list certified by the Secretary by the consenting votes of six Directors; or, the consenting votes of six Directors may order that no award shall be made for the ensuing year.

The award of the medal, if made, is to be for the calendar year commencing with the January after the meeting at which the award is made; and on January 1st one of the Secretaries of the Astronomical Society of the Pacific is to officially notify the recipient of the award, and on receiving a letter of acceptance, is to transmit the medal, engraved with the name and year. The name of the recipient of the medal is not to be made public until after the receipt of a letter of acceptance.

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* In response to a request made by one of the nominating observatories, the Board of Directors of the Society has construed the provision in Article V of the Statutes, referring to "astronomers worthy to receive the medal for the ensuing year," to cover services rendered during the life-time of the nominee.

The President of the Astronomical Society of the Pacific, in his address at the annual meeting of the Society in March is to announce the award and the reasons for making it.

VII. It is competent for the eleven Directors of the Astronomical Society of the Pacific, by a unanimous vote, and not otherwise, to substitute for any one of the Observatories named in Article V some other Observatory. It is desirable, though not essential, that three of the Observatories aforesaid shall be American and three Foreign.

Not more than one such substitution is to be made in any single calendar year.

RULES RELATING TO THE COMET MEDAL OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC.

I. A medal of bronze is established, as a perpetual foundation, to be given for the discovery of comets, as follows:—

The medal is to bear on the *obverse* side the effigy of a bright comet among stars, with the legend, "ASTRONOMICAL SOCIETY OF THE PACIFIC," around the border; and on the *reverse* the inscription, "THIS MEDAL FOUNDED IN 1890 BY JOSEPH A. DONOHOE, IS PRESENTED TO .... (the name of the discoverer) TO COMMEMORATE THE DISCOVERY OF A COMET ON .... (the date)."

It is to be understood that this medal is intended solely as a recognition of merit, and not as a reward.

II. The medal will be given to the actual discoverer of any unexpected comet.

III. The discoverer is to make his discovery known in the usual way, and, in order to simplify the work of the committee, which, in certain cases may be called upon to consider the merits of several independent discoveries of the same object, he should also address a letter to the Director of the Lick Observatory, which should state the exact time of the discovery, the position of the comet, the direction of its motion (when this can be determined), and the physical appearance of the object.

No application for the bestowal of the medal is required. The letters received from discoverers of comets will be preserved in the records of the Lick Observatory. Cable telegrams to the Lick Observatory are to be addressed to "Astronomer, San Francisco."

IV. All communications will be referred to a committee consisting of the Director of the Lick Observatory, *ex officio*, and of two other persons, members of the Astronomical Society of the Pacific, who are to be annually appointed by the Board of Directors. The decisions of this committee are to be final upon all points relating to the award of the medal. The committee will print an annual statement of its operations in the Publications of the Society.

Under ordinary circumstances the comet medal will be awarded within two months after the date of the discovery. In cases of doubt a longer period may elapse. The medal will not be awarded (unless under the most exceptional circumstances) for the discovery of a comet until enough observations are secured (by the discoverer or by others) to permit the calculation and verification of its orbit.

V. This medal is to be a perpetual foundation from and after January 1, 1890.

NOTICE TO MEMBERS.

In order to facilitate correspondence between the officials of the Society and its members and to insure the proper delivery of its Publications, all members are respectfully requested to notify the Secretary of any changes in post-office address.

Communications addressed to the undersigned will have prompt attention.

D. S. RICHARDSON,

Secretary Astronomical Society of the Pacific,
Room 748 Phelan Building, San Francisco, Cal.

NOTES FROM PACIFIC COAST OBSERVATORIES.

THE ORBITS OF ϵ *HYDRÆ*, AB, AND OF β 883.

By graphical methods orbits have been computed of AB of ϵ *Hydræ*, whose α for 1900.00 was $8^h\ 41^m$ and $\delta + 6° 47'$, and of β 883, whose α for 1900.00 was $4^h\ 5^m\ 40^s$ and $\delta + 10° 54'$.

The elements of ϵ *Hydræ* differ somewhat in node and inclination from those by Dr. AITKEN in *Lick Observatory Bulletin* No. 36, but they fully represent the observations.

The elements of β 883 represent the observations as well as do those of SCHOENBERG, given in *Astronomische Nachrichten*, **178**, p. 187, 1908, and about as well as those of SEE, given in *Monthly Notices*, **58**, p. 566, 1908. The differences in the three sets of elements are due mainly to the difference in the weights given the observations. These differences may be regarded as a measure of the uncertainty still attaching to our knowledge of the true orbit of this system.

The elements of AB of ϵ *Hydræ* are:—

$T = 1901.11$
$P = 15.63$ years
$e = 0.69$
$a = 0''.267$
$\Omega = 122°.7$
$i = 63°.29$
$\omega = 259°.46$
$\mu = 23°.032$

THE EPHEMERIS.

Date.	θ	p	Date.	θ	p
1909.825	200°.96	0''.20	1915.825	294°.29	0''.15
1910.825	214 .65	0 .19	1916.825	42 .51	0 .04
1911.825	229 .59	0 .19	1917.825	124 .91	0 .17
1912.825	244 .79	0 .19	1918.825	137 .75	0 .23
1913.825	260 .03	0 .19	1919.825	146 .74	0 .25
1914.825	275 .57	0 .18	1920.825	155 .93	0 .25

My elements of β 883 are (with those by SCHOENBERG and by SEE for comparison):—

	MISS BROWN	SCHOENBERG	SEE
$P =$	16.6 years	16.90 years	16.6 years
$T =$	1907.2	1907.39	1907.33
$e =$	0.42	0.42	0.47
$a =$	0″.22	0″.21	0″.24
$\Omega =$	22°.0	54°.4	33°.5
$i =$	38°.72	16°.08	35°.7
$\omega =$	207°.96	172°.95	197°.3
$\mu =$	22°.401		

THE EPHEMERIS.

Date.	θ	ρ	Date.	θ	ρ
1909.84	343°.42	0″.19	1915.84	47°.36	0″.30
1910.84	10 .69	0 .21	1916.84	56 .35	0 .28
1911.84	12 .17	0 .26	1917.84	61 .68	0 .27
1912.84	21 .92	0 .28	1918.84	79 .33	0 .23
1913.84	32 .56	0 .30	1919.84	95 .89	0 .20
1914.84	39 .09	0 .30	1920.84	118 .04	0 .17

FLORENCE BROWN.

THE BRIGHTNESS OF THE SATELLITES OF *MARS*.

The statement is made in some recent textbooks on astronomy that *Phobos* and *Deimos*, the two small satellites of *Mars*, can be seen only with very large telescopes and *then only by screening the light from the planet*. A series of measures of these two satellites was made by me in September and October of the present year, and this gave me the opportunity to confirm my impression of the error of this statement. A large telescope is indeed required to show these tiny bodies, and they can be seen only when *Mars* is comparatively near opposition, but under good conditions it is then unnecessary to protect the eye from the light of the planet. *Phobos*, the inner satellite, is very decidedly the brighter of the two, and can be seen, with the 36-inch, in the full light of *Mars* when less than 3″ from the planet's limb. *Deimos* is fainter, and is a difficult object in the planet's light when 10″ from the limb. At distances greater than these limits both satellites are readily visible without screening the light from *Mars*, when the seeing is good. My estimates make *Phobos* fully six times as bright as *Deimos* when at the same distance from the planet: that is, about two stellar magnitudes brighter.

November 19, 1909. R. G. AITKEN.

DECEMBER OBSERVATIONS OF HALLEY'S COMET.

Halley's Comet was observed with the 36-inch refractor on the nights of December 14th, 15th, 17th, and 18th. The measures of position show that the correction to Father SEARLE'S ephemeris was then about $+5^s$ in right ascension and about $+0'.2$ in declination. The comet appeared to be nearly round, the coma being 1′ ± in diameter, with a sharp nucleus. The halo around the comet extended over an area nearly 15′ in diameter, and was decidedly brighter and somewhat more extended on the following side. No other evidence than this could be found of a tail. The comet was estimated to be of the tenth magnitude. It was easily detected with the 3-inch finder of the 12-inch telescope on the night of December 10th.

December, 1909. R. G. AITKEN.

NOTE ON HALLEY'S COMET.

Halley's Comet is increasing rapidly in brightness. In the middle of December it was an easy object in a 6-inch telescope, and could be made out in a 3-inch. At this time the effective magnitude of the comet as a whole must have been about the tenth magnitude. The computed brightness of the comet on December 16th, according to CROMMELIN, was $13^m.0$ on the assumption that the brightness varies as $\frac{1}{r^2 \Delta^2}$, and $12^m.0$ on the assumption that the brightness varies as $\frac{1}{r^4 \Delta^2}$. From this it will be seen that the comet's increase in brightness has been quite rapid, and departs very far from the value given by the ordinarily accepted formula $\frac{1}{r^2 \Delta^2}$. Comets are so erratic in this respect that no fixed formula of light-increase can be adopted. From a long series of estimates by various observers on Comet 1898 I,[1] the writer found that this comet followed quite closely the purely empirical formula $\frac{1}{r^7 \Delta^2}$; using this ratio, the calculated magnitude of Comet Halley on December 16th would have been about 10.6.

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[1] *A. N. Erg. H.*, No. 3.

Photographs taken with the Crossley reflector on December 12th, 13th, and 14th recorded a coma of about 1′ in diameter, with an exposure of thirty-five minutes; an exposure of two hours shows the surrounding halo, though very faintly in the outer portions, with a diameter of about 5′. These plates show also very faint traces of a short tail, following and directed slightly to the north. As the angle at the comet between the radius vector and the line connecting the comet and the earth was less than 2° on this date, this may correspond to a tail of moderate length.

The following ephemeris has been computed by Father SEARLE, assuming perihelion as April 19.69.

			α			δ
1910 January	2	2h	14m	37s	+11°	23′.3
	4		7	50	11	5.2
	6	2	1	21	10	47.8
	8	1	55	11	10	31.1
	10		49	21	10	15.3
	12		43	49	10	0.4
	14		38	35	9	46.4
	16		33	39	9	33.4
	18		29	0	9	21.3
	20		24	38	9	10.2
	22		20	31	9	0.0
	24		16	38	8	50.6
	26		12	59	8	42.1
	28		9	34	8	34.5
	30		6	21	8	27.6
February	1		3	18	8	21.5
	3	1	0	25	8	16.2
	5	0	57	43	8	11.5
	7		55	10	8	7.5
	9		52	46	8	4.0
	11		50	29	8	1.0
	13		48	19	7	58.7
	15		46	15	7	56.9
	17		44	17	7	55.5
	19		42	24	7	54.5
	21		40	36	7	53.8
	23		38	52	7	53.5
	25		37	11	7	53.6
	27		35	33	7	53.8
March	1		33	57	7	54.3
	3		32	23	7	54.9
	5	0	30	51	+7	55.8

According to elements by Dr. SMART, the comet will be closest to the Earth on May 20th, when its distance will be 14,300,000 miles. There is considerable probability that the Earth will pass through the tail on May 18th.

H. D. CURTIS.

GENERAL NOTES.

The Copley Medal of the Royal Society has been awarded to Dr. G. W. Hill for his researches in mathematical astronomy.

"Dr. Hill's work in the branch of astronomy that is farthest removed from popular view, and his exacting application of the higher mathematics to problems requiring the most rigid and complicated demonstration and proof, have done much to facilitate recent progress and to place that progress upon a sure basis."

A Bright Meteor.—On December 12th at 6:40 P. M., Pacific Standard Time, a very brilliant meteor was seen by Miss Nellie Ford and Miss Marjorie Driscoll, students in general astronomy at Stanford University. It appeared about ten degrees west of the Pole Star, moved very slowly westward and disappeared behind the western hills after being visible about half a minute (possibly exaggerated). The meteor was many times brighter than *Venus,* and its trail was visible for the whole length of its path for ten or fifteen seconds after the meteor disappeared. S. D. T.

The library of the late Professor Newcomb has been purchased by Mr. John Claflin for the College of the City of New York.

Under a resolution of the Board of Directors of the Astronomical Society of the Pacific passed July 13, 1907, the by-laws of the Society, together with the statutes governing the bestowal of the Bruce Medal and the rules relating to the Donohoe Comet-Medal, have been reprinted in this number of the Publications. Amendments to the by-laws made since they were last printed in 1897 have been incorporated.

Dr. Karl Schwarzschild, professor of astronomy at Göttingen, has been appointed director of the Astrophysical Observatory at Potsdam.

NEW PUBLICATIONS.

Annales de l'Observatoire Royal de Belgique. Tome XII. Fascicule I.

Les co-ordonnées absolues des étoiles déduites des feuilles héliogravées de la Carte du ciel.

Correction de la position et diamètre de *Mercure* déduits des observations de contact effectuées lors du passage du 15-14 Novembre 1907.

Observations faites au cercle méridien de Repsold en 1908.

Observations solares effectuées á Uccle en 1908.

Bruxelles. 1909. Folio. 307 pp. Paper.

Annuarie pour l'an 1910 publié par le Bureau des Longitudes. Paris. Avec des Notices Scientifique. 24°. 834 pp. paper.

Annuario del Observatorio Astronómico Nacional de Tacubaya parael año de 1910. Mexico. 1909. 16°. 602 pp. Paper.

Astronomische Beobachtungen auf der Königlichen Universitäts-Sternwarte zu Königsberg. Abteilung 42. Rektaszensions-Beobachtungen von 4066 Sternen. Angestellt von FRITZ COHN. Königsberg. 1909. Folio. 355 pp. Paper.

BEMPORAD, A. L'Assorbimento selettivo della radiazione solare nell'atmosfera terrestre. Roma. 1909. 4°. 111 pp. Paper.

BALCELLS, P. MARIANO. L'Observation solaire. Mémoires de l'Observatoire de l'Ebre. No. 2. Barcelone. 1909. 4°. 133 pp. Paper.

ENEBO, SIGURD. Beobachtungen veränderlicher Sterne. Kristiania. 1909. 8°. 60 pp. Paper.

JONES, HARRY C., and ANDERSON, JOHN A. The absorption spectra of solutions. Washington. 1909. 4°. 110 pp., with 81 plates. Cloth.

KOCH, JOHN. Dispersionsmessungen an Gasen im sichtbaren und im ultraroten Spektrum. Upsala. 1909. 4°. 60 pp. Paper.

Meddelanden från Lunds Astronomiska Observatorium. Serie II. Lund 1909. 4°. Paper.

No. 5. Über die Bewegung der Bahnebenen der Satelliten in unserem Planetensystem. C. V. L. CHARLIER. 35 pp.

No. 6. Sur une classe de singularités dans le problème de *n* corps, par HENRIK BLOCK. 57 pp.

Neue Annalen der K. Sternwarte in München. Band IV. Katalog von 1436 Sternen, hauptsächlich Zenitsternen. München. 1909. Folio. 242 pp. Paper.

Perth Observatory. Vol. 3. Meridian Observations 33° to 35° south. Epoch 1900. Perth. 1909. Folio. 59 pp. Cloth.

Publications de l'Observatoire Central Nicolas. Série II. Vol. XVIII, III. Beobachtungen am grossen Zenitteleskop. A. ORLOFF. St. Pétersbourg. 1908. Folio. 66 pp. Paper.

Publikationen der Kaiserlichen Universitäts-Sternwarte zu Jurjew. (Dorpat.)

A. ORLOFF. Graphische Methode zur Auswahl der Sternpaare für die Breitenbestimmung nach der Methode gleicher Zenitdistanzen.

E. SCHOENBERG. Sternbedeckungen durch den Mond beobachtet in den Jahren 1905-09.

Beobachtungen des *Jupiter* am Zenittelescop im März 1908. Dorpat. 1909. Folio. 24 pp. Paper.

Mitteilungen der Grossh. Sternwarte zu Heidelberg. Karlsruhe. 1909. 8°.

XV. Die Bahnen der am 3 August und am 28 September, 1905, erschienenen hellen Meteore. P. MOSCHICK. 32 pp.

XVI. Doppelsternmessungen am zwölfzölligen Refraktor des Astronomisches Instituts. 59 pp.

XVII. Helligkeitsmessungen von lang periodischen Veränderlichen. 97 pp.

The tidal and other problems. T. C. CHAMBERLAIN, F. R. MOULTON, and others. Washington. 1909. 8°. 264 pp. Paper.

Solar eclipse expedition to Flint Island, January 3, 1908. F. K. McKLEAN and others. Suffolk. Folio. 18 pp., with 15 plates. Cloth.

ZINNER, E. Über die sekularen Störungen im planetarischen Rotationsproblem. Lund. 1909. 8°. 25 pp. Paper.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS, HELD IN THE STUDENTS' OBSERVATORY, BERKELEY, CALIFORNIA, NOVEMBER 27, 1909, AT 7:30 P. M.

In the absence of President **CAMPBELL**, the chair was occupied by Professor A. O. **LEUSCHNER**.

The following were elected to membership in the Society:—

Mr. **JOHN S. HODGIN**,
Mr. **THOMAS T. GREAVES**,
Mr. **CHARLES F. HART**,
Mr. **E. D. RODGERS**.

Application for life membership in the Society was received from Dr. C. D. **PERRINE** and favorably acted upon.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE STUDENTS' OBSERVATORY, BERKELEY, CALIFORNIA, NOVEMBER 27, 1909, AT 8 P. M.

Professor A. O. **LEUSCHNER** presided over the meeting.

Dr. **HEBER D. CURTIS**, of Lick Observatory, delivered a most interesting lecture upon "Astronomical Problems of the Southern Hemisphere and the Work of the D. O. Mills Expedition." The lecture was illustrated by many excellent lantern slides, throwing light upon the scientific subjects discussed, and descriptive also of the Chilean environment in which Dr. **CURTIS** has spent the past two years as director of the expedition.

The exercises of the evening closed with an illustrated lecture by Dr. T. J. J. **SEE**, of the Mare Island Naval Observatory, on "The Origin of the So-Called Craters on the Moon." According to the theory of Dr. **SEE**, the "craters" are the result of collision between the moon and bodies from outer space. The remarks of the speaker called forth some adverse criticism from members present and resulted in a spirited debate.

Adjourned.

D. S. **RICHARDSON**,
Secretary.

OFFICERS OF THE SOCIETY.

Mr. W. W. CAMPBELL	*President*
Mr. G. E. HALE	*First Vice-President*
Mr. F. MORSE	*Second Vice-President*
Mr. E. J. MOLERA	*Third Vice-President*
Mr. D. S. RICHARDSON	*Secretary and Treasurer*
Mr. R. G. AITKEN (Mount Hamilton, Cal.)	*Secretary*

Board of Directors—Messrs. AITKEN, BURCKHALTER, CAMPBELL, CRAWFORD, CROCKER, CUSHING, GALLOWAY, HALE, MOLERA, RICHARDSON.

Finance Committee—Messrs. MOLERA, CROCKER, CUSHING.

Committee on Publication—Messrs. TOWNLEY, MADDRILL, CURTIS.

Library Committee—Messrs. CRAWFORD. TOWNLEY, EINARSSON.

Comet-Medal Committee—Messrs. CAMPBELL (ex-officio), TOWNLEY, CURTIS.

NOTICE.

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